1992

SN10: reliability and validity

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SN1Ø; Reliability and Validity

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Electrophysiologic tests are beneficial for supplying audiological information for infants, uncooperative children and multiply-handicapped individuals. The Auditory brainstem response (ABR) has achieved popularity because it is "robust against the use of sedatives and so may be used to provide threshold estimates in cases where the patient cannot remain passive and calm during testing." (Bell and Thorton, 1988 p. 21) ABRs may be used to identify hearing impairments from early infancy through adulthood. Click stimuli and high frequency tone pips are often used for ABRs because they elicit responses within 10 dB of the behavioral threshold. (Davis and Hirsh, 1979 and Davis et al, 1985) However, a limitation of click stimuli is that they provide only high frequency information in the 2000 Hz to 4000 Hz range. (Davis and Owens, 1985 and Davis et al, 1985) To select appropriate hearing aids for hearing impaired children and to make appropriate educational decisions it is desirable to obtain frequency specific thresholds at lower frequencies.

Various methods have been developed to obtain information in the lower frequencies. (Davis and Hirsh, 1976, Davis et al, 1985, and Silman and Silverman, 1991) The Frequency Following Response (FFR) which elicits neural firing at a rate of 500 times a second, detects responses at a low frequency. According to Davis (1976, p. 8), it "is clearest at 500 Hz, but its threshold is about 40 dB SL and is not entirely reliable because of individual differences."

Other methods use masking for the high frequencies so low frequency information may be obtained. "However there has not been sufficient evidence to demonstrate convincingly that ABR testing with masking is a sensitive and reliable clinical procedure with young children." (Weber, 1987 p. 50S)

Galambos et al (1981) described improvements for detection of the 40 Hz MLR now known as Auditory Steady State Evoked Potential (SSEP) elicited by 500 Hz tone bursts. There are conflicting reports on the reliability of the SSEP. For instance, "Liden et al (1985) describe the SSEP being closely related to behavioral thresholds in sleeping adults. Others (Kankkunen et al, 1985; Sammeth et al, 1985) report that the responses are too unstable for clinical use with sleeping patients" (Weber, 1987 p. 52S); therefore, making them unsuitable for many infants and children.

The Middle Latency Response (MLR) also provides low frequency information. According to Mendel et al (1975) MLR thresholds were consistent whether subjects were fully awake, sleeping or lightly sedated. However, Davis (1976) states that MLR responses are unsatifactory in children under adequate sedation.

Davis and Hirsh (1979) described the Slow Negative Wave (SN10) which is not dependent on the subject's state. "If sedation is to be employed, we see no good alternative to SN10 for 500 Hz stimuli" (Davis et al, 1985 p. 58). Davis (1985, p. 170) recommended a procedure to obtain a four

frequency audiogram by using "brief tone bursts at 4,000, 2,000, 1,000, and 500 Hz. With the 4,000 and the 2000 Hz stimuli a clear Jewett Wave V (Jv) response can be evoked even at low intensities." At 1000, and 500 Hz it is necessary to use the SN10. Davis (1985) reported this scalp negative wave SN10 can be identified down to approximately 10 dB SL in young adults; however, the author did not provide empirical evidence for this claim.

The SN10 has not achieved widespread use, possibly because reliability and validity have been questioned. No large scale study has been carried out to validate the SN10 against behavioral thresholds. This study was designed to assess reliability and validity of the 500 Hz SN10 for adult, non-sedated patients. Furthermore, the need for training and experience in interpretation of responses was assessed by comparing experienced and inexperienced "readers." To put the 500 Hz SN10 data in perspective, data for 2000 Hz Jewett Wave V were also collected.

METHOD

Subjects

Eight subjects (4 males, 4 females), ranging in age from 18 to 36 years (mean 21 years), whose hearing sensitivity and typanometric measures were within normal limits, participated in eight to nine consecutive weekly sessions. Pure-tone thresholds for audiometric frequencies from 250 to 8000 Hz

were less than or equal to 20 dB (nHL) for all subjects during the initial and final sessions. Hearing screenings for each intermediary test session administered at 5 dB (SL) indicated that no subject's thresholds shifted more than 5 dB during the course of the study. Tympanograms obtained at each session for all subjects were well within normal limits for tympanometric peak pressure (+15 to -30 daPa) and static immittance (0.4 ml to 1.0 ml).

Four experienced readers and four inexperienced readers judged thresholds from the 164 sets of traces. The four experienced readers (Certified Audiologists) had two to five years of experience with ABRs including SN10s.

The four inexperienced readers (Audiology students) had completed one year of graduate study at Central Institute for the Deaf. Three of the students had previously attended a course that devoted several lectures to ABR, and the fourth student had received training at St. Louis Childrens Hospital (SLCH).

Procedure

Each test session consisted of a hearing screening, tympanometry, and ABR. ABRs were obtained from each non-sedated subject at 500 Hz and 2000 Hz at each session. The subject reclined in a darkened sound treated audiometric booth. Data for the current study were collected as part of a research project comparing ABR and MLR. The ABR traces for

this study were obtained after other ABR and MLR data had been collected, approximately one hour after testing had begun. At times it was difficult for subjects to remain still under these circumstances. For some subjects at certain sessions testing was not completed for 500 Hz and/or 2000 Hz because the subject was too active.

ABRs were obtained using a Madsen 2250. Four-millimeter silver chloride disposable recording electrodes were placed at Cz, A1, and A2, with a ground at Fpz. Cz was referenced to the ipisilateral ear. Inter-electrode resistance was below 5 KOhms. Stimuli were 2-1-2 tone bursts with polarity of rarefaction presented through Madsen Electronics MSH87 circumaural earphones. Stimuli were presented at a rate of 30/sec and 2000 responses were averaged for each trace. A time window of 20 msec was used with a 6 msec stimulus onset delay for 500 Hz and no stimulus onset delay for 2000 Hz. A medium filter with cut off frequencies of 48 and 1539 Hz and a 24 dB octave roll off were employed with respect to the electrical response.

PREPARATION OF TRACE SETS

The 164 sets of traces included nine sets of 500 and 2000 Hz traces from subject 1 and eight sets of traces from subjects 2, 3, 4, 5, 6, and 7. The data for subject 8 consisted of three trace sets for 2000 Hz and five sets for 500 Hz. Sets of traces from six patients (11 months to 5

years of age) were mixed into the data sets to serve as foils. Adult subject sets (see Figure 1) began with an intensity level of 60 dB (nHL) for the first trace followed by decreasing intensity levels such as 30 dB (nHL) and 15 dB (nHL). Based on experimenter judgement stimulus level was decreased further to obtain threshold for each subject. The scaling factor for the display amplitude was noted. To reduce reader bias the sets of traces were prepared so that absolute dB values would not be known to the reader. (see Figure 2) The absolute dB level was replaced with a relative dB level referenced to 60 dB (nHL) which served as the zero point. For example 15 dB nHL would have been labeled -45. The readers did not know that trace sets began with 60 dB nHL, but did know that "zero" represented a high intensity stimulus. In fact trace sets for the patients began at levels as high as 90 dB (nHL). The center frequency of the test stimulus, the sweep time (ms), and the number of accepted sweeps were marked. The sets of traces for each frequency region were shuffled and numbered #1-#84 for the 500 Hz trace sets and #85-#164 for 2000 Hz trace sets.

Experienced readers were instructed to "read" the traces in the same manner they would when testing a patient. In addition the written guidelines (see Appendix A) supplied for the students were also given to the experienced readers. Prior to judging the traces, the four inexperienced readers received a one-hour instruction session from a Certified

Figure 1
Example of a 500 Hz SN10 Trace Set Before It Was Prepared For The Readers

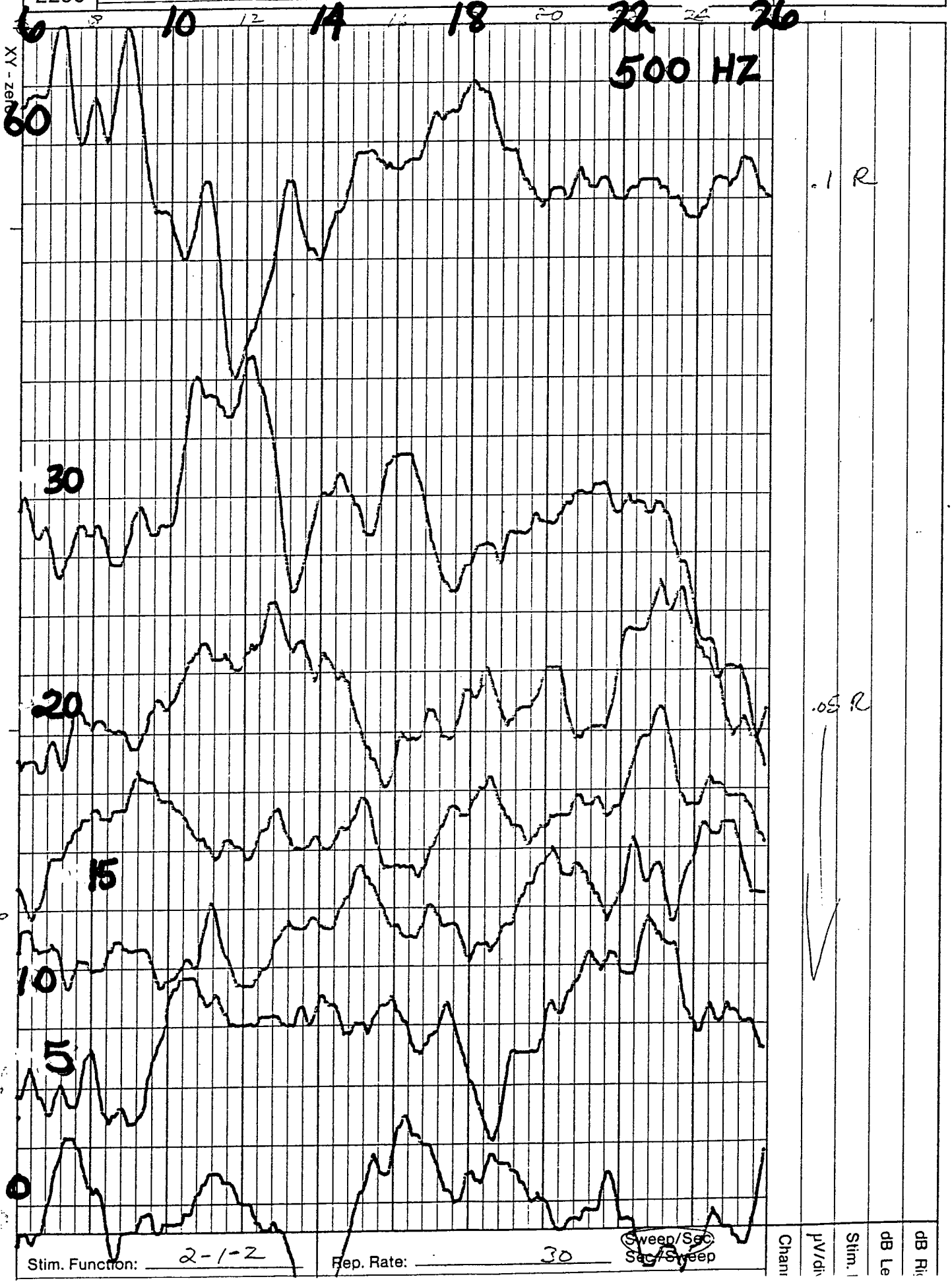
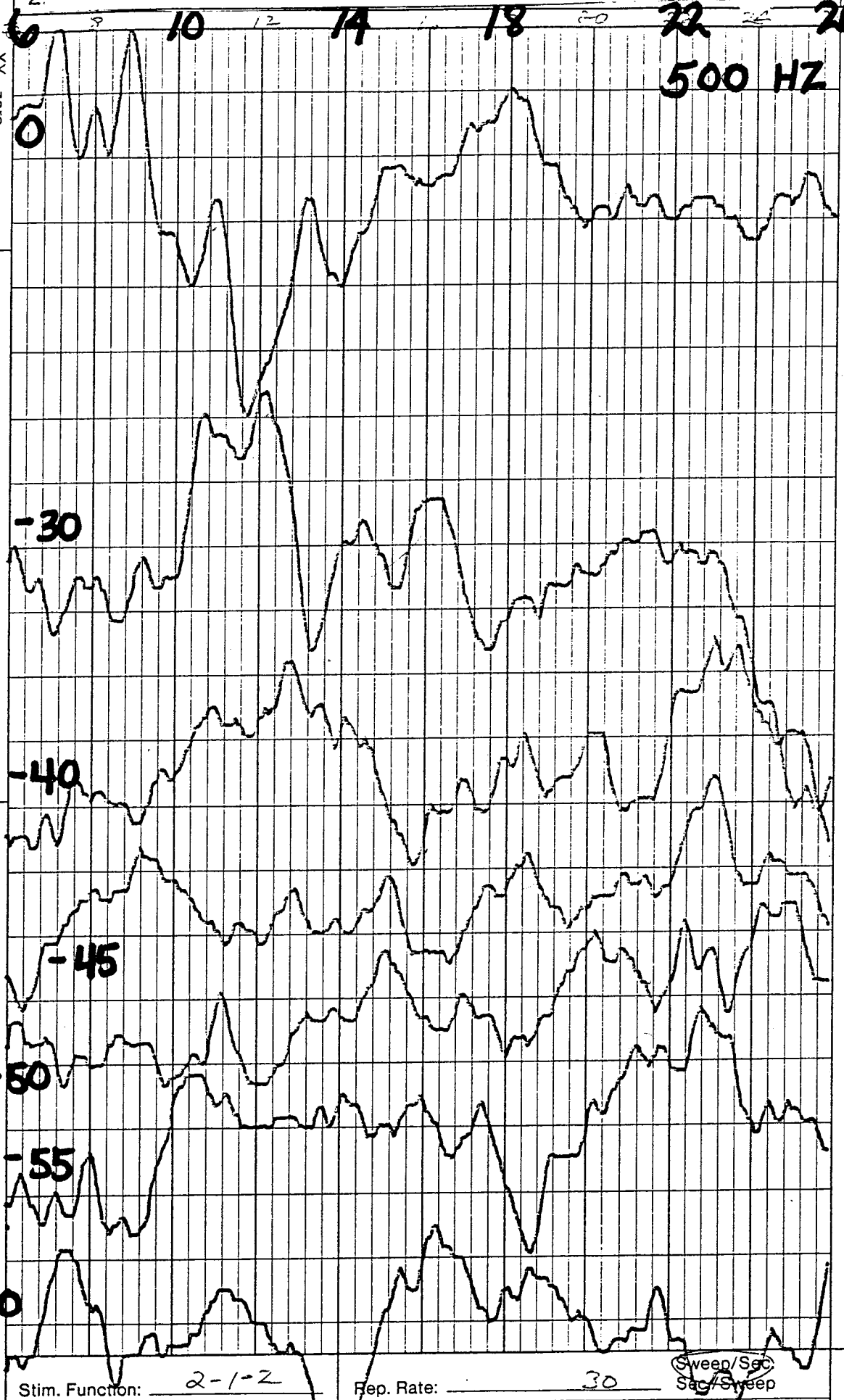


Figure 2
Example of a Prepared 500 Hz Trace Set Given To Readers to Estimate Threshold



Madsen Electronics

Size: Expand.

Order - 16 - 0177

4000

Stim. Function: 2-1-2

Rep. Rate: 30 Sweep/Sec Sec/Sweep

Channel

μV/div

Stim. Rate

dB Left

dB Right

Audiologist who had used SN1Øs clinically for over 8 years. Readers were instructed to begin with 2ØØØ Hz traces (#85 to #164) because in general these were "easiest to read." For each set of traces three questions were asked:

1. What was the relative decibel level of the softest trace exhibiting the response? If two traces were recorded for the chosen level subjects were asked to state whether they saw the response for one or both (i.e., A and/or B).
2. What was the relative decibel value that represents "threshold"? Readers were allowed to interpolate 5 dB from the traces present.
3. Should additional traces have been run? If yes, readers were asked to specify the traces they would have obtained.

RESULTS

Experienced vs Inexperienced reader estimates of threshold for the 2ØØØ Hz ABR compared with behavioral thresholds for each subject revealed that both groups of readers made close approximations of actual threshold for seven of the eight subjects. (see Figure 3) Based on average judgements across the inexperienced readers, they predicted thresholds within 5 dB of behavioral threshold for six of the eight subjects i.e., subject #7 was within -Ø.3 dB, #2 within Ø.8 dB, #1, #6 and #8 were within 2.8 dB and subject #4 was within -3.5 dB. Predicted thresholds were

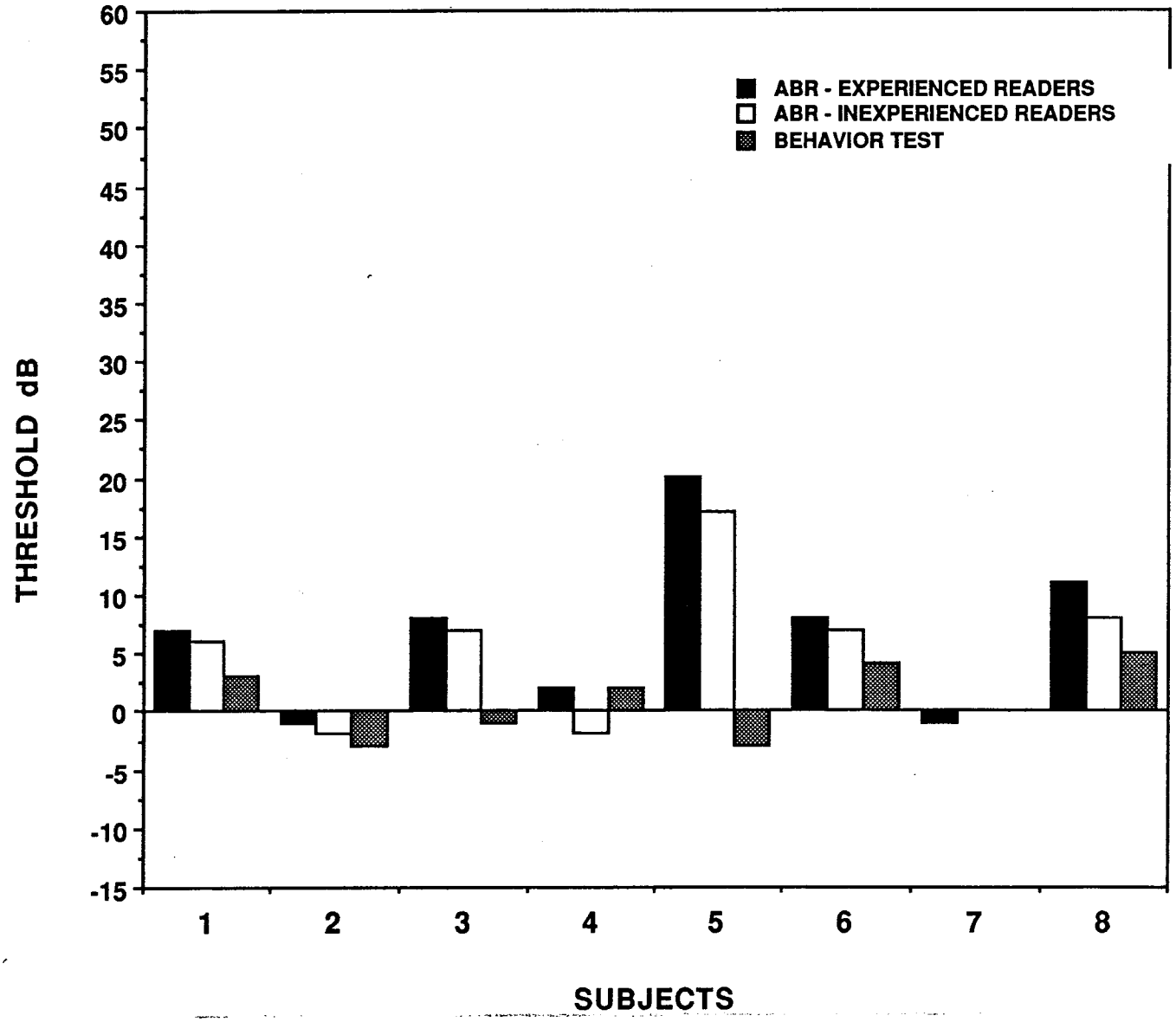


Figure 3
Experienced vs Inexperienced reader mean estimates of threshold for the 2000 Hz ABR compared with behavioral thresholds for subjects #1 thru #8.

within 7.9 dB of behavioral threshold for subject #3 and within 19.1 dB for subject #5. Overall, the average 2ØØØ Hz ABR estimates of threshold of the inexperienced readers were 4.Ø dB above behavioral threshold with a range of -Ø.3 to 19.1 dB SL. Threshold estimates for each subject showing results of each session are shown in Appendix B.

The experienced readers also made judgements of 2ØØØ Hz thresholds within 5 dB for five subjects i.e., subject #4 was within Ø.2 dB, #7 within -Ø.6 dB, #2 within 1.Ø dB, and subjects #1 and #6 were within 4.2 dB. Predicted thresholds were within 6.2 dB for subject #8, within 9.3 dB for subject #3 and within 22.5 dB of behavioral threshold for subject #5. Overall the average ABR threshold estimates of the experienced readers were 5.8 dB (range of Ø.2 to 22 dB SL) above behavioral threshold.

As illustrated in Figure 4, inexperienced readers judged 5ØØ Hz SN1Ø thresholds within 5 dB of behavioral thresholds for three of the eight subjects i.e. subject #2 and #4 were within 2.6 dB and #7 was within 4.7 dB. They were within 6.9 dB of behavioral threshold for subject #1, within 11.9 dB for subject #6, within 13.6 dB for #3 and within 15.2 dB for #8. For subject #5 the inexperienced readers were within 32.3 dB of behavioral threshold. Inexperienced readers judgements of 5ØØ Hz SN1Ø across all eight subjects were an average of 11.2 dB (standard deviation 1Ø.1) above behavioral threshold. Threshold estimates for each subject showing

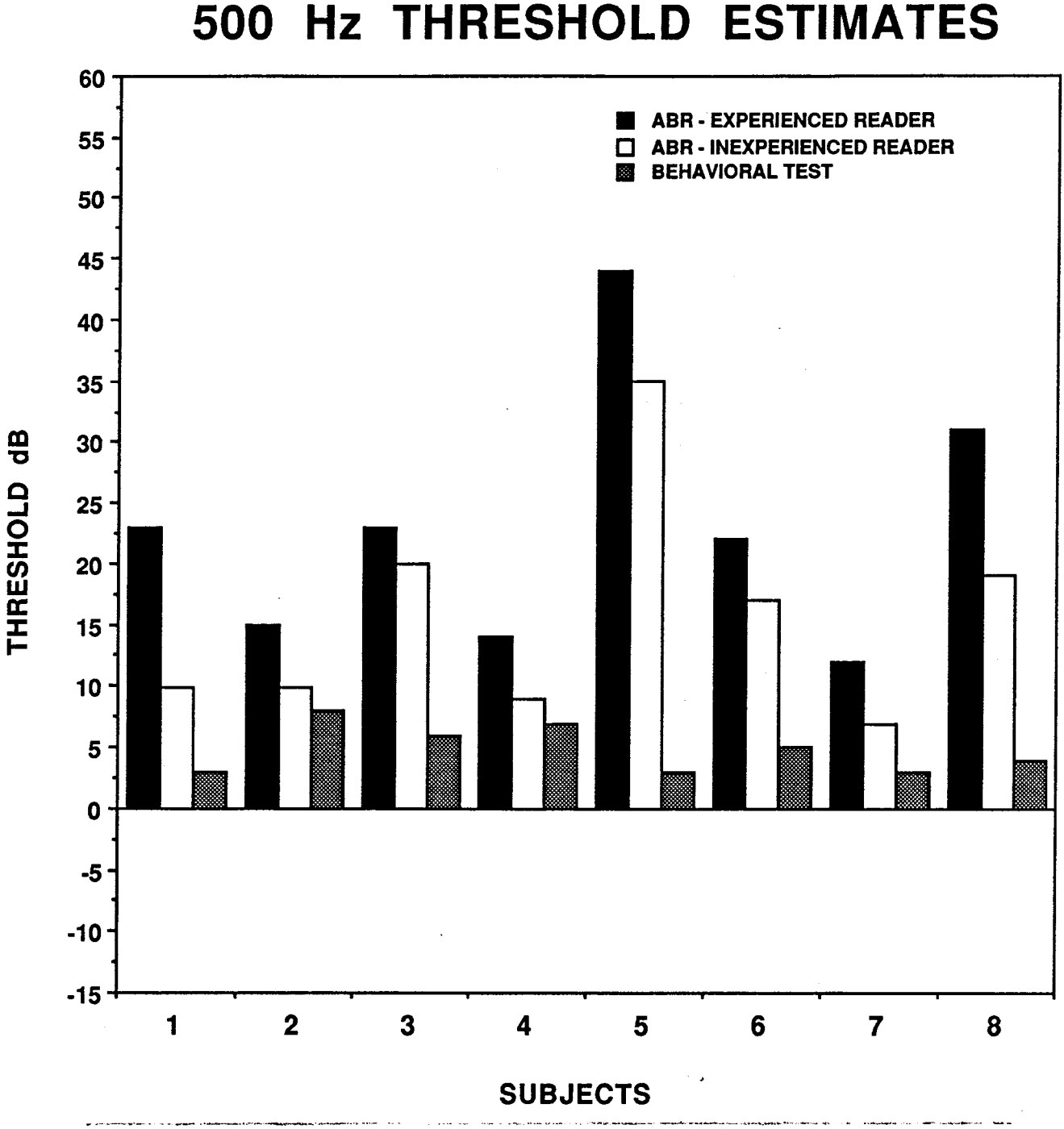


Figure 4
Experienced vs Inexperienced reader mean estimates of threshold for the 500 Hz SN10 compared with behavioral thresholds for subjects #1 thru #8.

results of each session are shown in Appendix C.

Experienced readers judged the 500 Hz SN10 within 10 dB of behavioral threshold for three subjects i.e., subject #4 was within 7.2 dB, #2 within 7.5 dB and #7 within 9.1 dB. Experienced readers were within 16.7 dB of behavioral threshold for subjects #3 and #6 and within 20.0 dB for subject #1. For subject #8 they were within 26.7 dB of behavioral threshold and for subject #5 they were within 41.0 dB. The experienced readers' judgements for the 500 Hz SN10 were an average of 18.5 dB (standard deviation 11.7) above behavioral threshold.

It should be noted that subject #5 produced sets of traces that were judged farthest from behavioral threshold for both 500 Hz SN10 and 2000 Hz data for both groups of readers.

Overall both groups of readers 2000 Hz ABR judgements were on average of 4.9 dB (standard deviation 7.3) above the mean of the 2000 Hz behavioral thresholds across the eight subjects. The overall judgements of both groups of readers for 500 Hz SN10 were within an average of 14.6 dB (standard deviation 11.4) of the mean of behavioral thresholds across the eight subjects.

Test-retest reliability for experienced readers was assessed by using the range of threshold estimates across the test sessions as the reliability measure. For example reader #11 estimated threshold as low as 10 dB (nHL) and as high as

EXPERIENCED READERS RANGE OF ESTIMATIONS FOR 500 Hz AND 2000 Hz

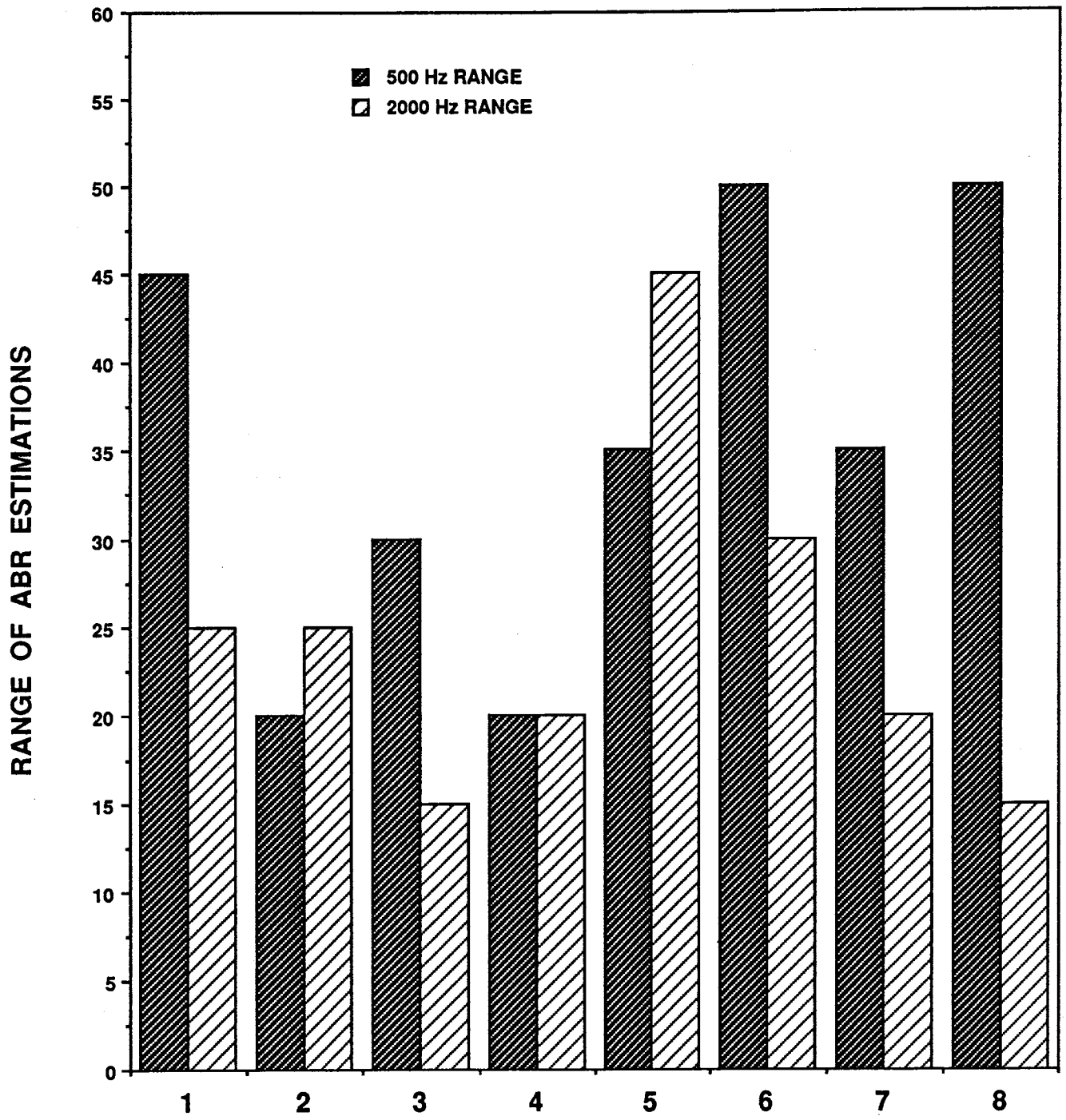
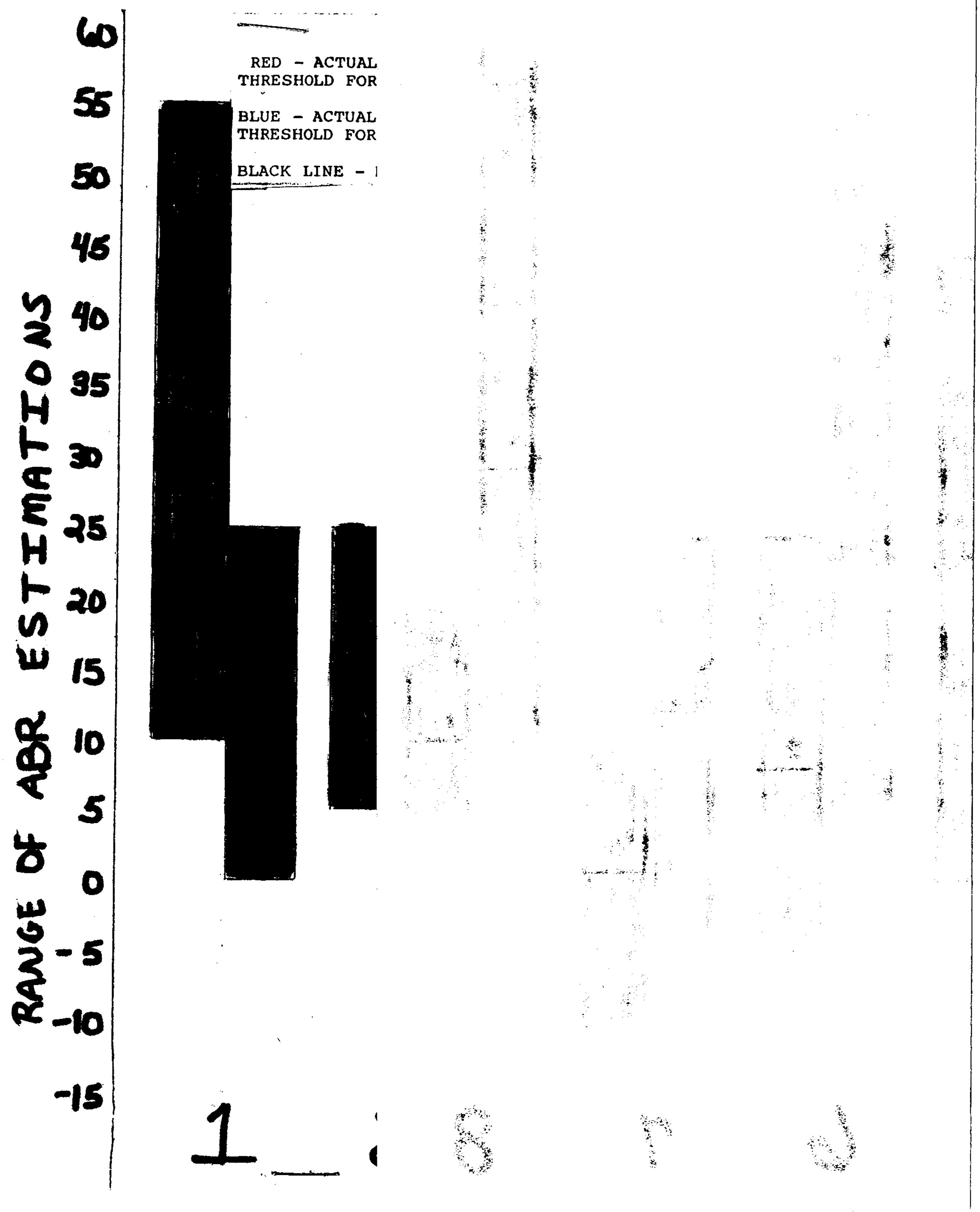


FIGURE 5a

DARK AREA - 500 Hz RANGE - REPRESENTS THE RANGE FROM THE LOWEST TO THE HIGHEST JUDGEMENT OF THRESHOLD FOR THE 500 Hz SN10 ACROSS EXPERIENCED READERS

LIGHT AREA - 2000 Hz RANGE - REPRESENTS THE RANGE FROM THE LOWEST TO THE HIGHEST JUDGEMENT OF THRESHOLD FOR THE 500 Hz SN10 ACROSS EXPERIENCED READERS


RED - ACTUAL
THRESHOLD FOR
BLUE - ACTUAL
THRESHOLD FOR
BLACK LINE -
RANGE OF ABR ESTIMATIONS
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
1

30 dB nHL for subject #1 across the nine test sessions, yielding a test-retest value of 20 dB. The range of test-retest values of the 4 experienced readers for the 8 subjects across the test sessions for 500 Hz and 2000 Hz is shown in Figure 5a. Figure 5b shows the same information in dB SL with the mean threshold estimate denoted.

Readers were allowed to interpolate 5 dB from the traces present and this data revealed that 45% of the time the experienced readers interpolated 2000 Hz trace sets and 51% of the time they interpolated the 500 Hz trace sets. The data revealed that 35% of the time the inexperienced readers interpolated the 2000 Hz trace sets and 28% of the time they interpolated the 500 Hz trace sets.

The readers' request for additional traces to be run across the eight subjects revealed experienced readers requested additional traces for 48% of the 2000 Hz trace sets and they requested additional traces for 54% of the 500 Hz trace sets. Inexperienced readers requested traces for 26% of the 2000 Hz trace sets and 38% of the 500 Hz trace sets.

DISCUSSION

As expected the data supports the 2000 Hz ABR Jv as a valid measure. ABR threshold judgements from both groups of readers were within approximately 5 dB of behavioral thresholds.

Within limits, the 500 Hz SN10 appears to be a valid estimate of low frequency thresholds. Overall, reader judgements for 500 Hz with SN10 were within 15 dB (standard deviation 11.4) of the actual behavioral thresholds. This is close to, but not quiet as good as the 10 dB SL value reported by Davis (1985). However, our findings may have been influenced by the fact the subject's 500 Hz SN10 data was not collected until approximately one hour after initial ABR testing had begun for each session and were not in an optimal state of relaxation. This would coincide with Davis's (1985, p. 174) specification that "complete muscular relaxation is necessary."

Subject #5 provided extremely poor ABR responses to both 500 Hz and 2000 Hz stimuli. If this subject was excluded the 500 Hz SN10 data would have been within 11 dB of behavioral threshold. However, subject #5 serves to remind us that ABR may at times not be a good estimate of behavioral threshold. Thus, the clinical practice of recommending follow-up with behavioral hearing tests is strongly supported. Furthermore, if hearing aids are fit based on ABR data close observation is needed to look for behavioral symptoms of over-amplification.

Surprisingly inexperienced readers judged 500 Hz SN10 thresholds closer to behavioral thresholds than experienced readers. Perhaps the inexperienced readers made closer interpolations of the ABRs because they were influenced by

suspecting that threshold would be close to the lowest relative level tested and therefore were influenced more by the lower limits of test traces. The experienced readers appeared more conservative in their choices and may have been less inclined to be influenced by the test array of traces. Also, experienced readers may be more aware of negative consequences resulting from "false negatives" (i. e, calling a trace normal when in fact it is abnormal).

The data of the 500 Hz SN10 and the 2000 Hz ABR revealed a wide range of variability on test-retest measures across sessions for all subjects. The variability for the range of the difference between the lowest and highest estimate, among the four experienced readers for each subject, was at best 15 dB for subjects #3 and #8 and at worst 45 dB for subject #5 for 2000 Hz data. The 500 Hz SN10 variability for the range of the difference between the lowest threshold estimate to highest threshold estimate, among the four experienced readers across the eight subjects, was at best 20 dB for subjects #2 and #4 and at worst 50 dB for subjects #6 and #8.

It is important to note that the largest variability of threshold judgements for both the SN10 and 2000 Hz were for subject #5. Review of the traces for subject #5 showed that the lowest level tested for five out of eight sessions was 30 dB (nHL). In contrast, the audiologist was able to obtain traces for other subjects at levels such as 5 or 10 dB (nHL). In conferring with Kay Rabbitt Park, (who performed the tests

and who has recently been involved in collecting normative data), she acknowledged that when obtaining normative data on non-sedated subjects it is not unusual to find adult subjects whose ABR estimates do not approximate behavioral threshold.

The study revealed the experienced readers interpolated thresholds more often than the inexperienced readers for both the 2000 Hz and 500 Hz data. Instead of accepting a lower "noisy" trace the experienced readers appeared more likely to accept a higher clearer trace and interpolate 5 dB.

The data from the study revealed that both experienced and inexperienced readers requested additional traces for the 500 Hz more often than the 2000 Hz. However, the experienced readers requested additional traces at near threshold levels more often for both the 2000 Hz and 500 Hz trace sets than inexperienced readers. If these had been obtained perhaps they would have estimated lower threshold.

In conclusion, this study supports the use of the SN10 to measure 500 Hz ABR. In general it approximates behavioral threshold within 15 dB for non-sedated adult subjects. Thus 500 Hz with SN10 may be used to provide low frequency information necessary to facilitate hearing aid selection for infants and children.

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Appendix A

1. Written Guidelines Supplied To The Readers
2. Experimental Parameters
3. Sample Traces

Appendix A

INSTRUCTION NOTES FOR JUDGING ABR TRACES

The following information and instructions were given to both the inexperienced and experienced readers.

Purpose of the Project:

To assess reliability and validity for 2000 Hz and 500 Hz responses with ABR.

GENERAL RULES:

1. The higher the intensity, the shorter the latency and the larger the amplitude. (This rule is the most important in determining threshold.)
2. Background noise is the degree of deviation from baseline of the EEG regardless of the stimulus. Example: A trace recorded with no stimulus or a stimulus below threshold "should" be almost a straight line.
3. In order to be considered a response, amplitude must be larger than background noise or repeatable at the same level.
4. Locate the response at the loudest level.
5. As intensity is lowered, follow the waveform response until it disappears.
6. The softest level where a response can be identified is considered "threshold".
7. The reader may extrapolate or interpolate 5 dB if he choses.

8. The largest response will in general be elicited by a stimulus of 60 - 70 dB.

IDENTIFYING 2000 Hz THRESHOLDS (JEWETT V)

1. Responses are usually sharp and clear.

2. Although latency does increase with decreased intensity, it is a small amount, sometimes difficult to see.

3. Response to a 60 dB nHL stimuli is usually seen at approximately 7 msec.

IDENTIFYING 500 Hz THRESHOLDS (SN10)

1. Responses are usually more rounded than those elicited by high frequencies. (We are now looking at the SN10 - not Wave V).

2. The SN10 is labeled as it occurs at approximately 10 msec with a 30 dB stimulus.

At 60 dB it is usually seen between approximately 8 - 10 msecs.

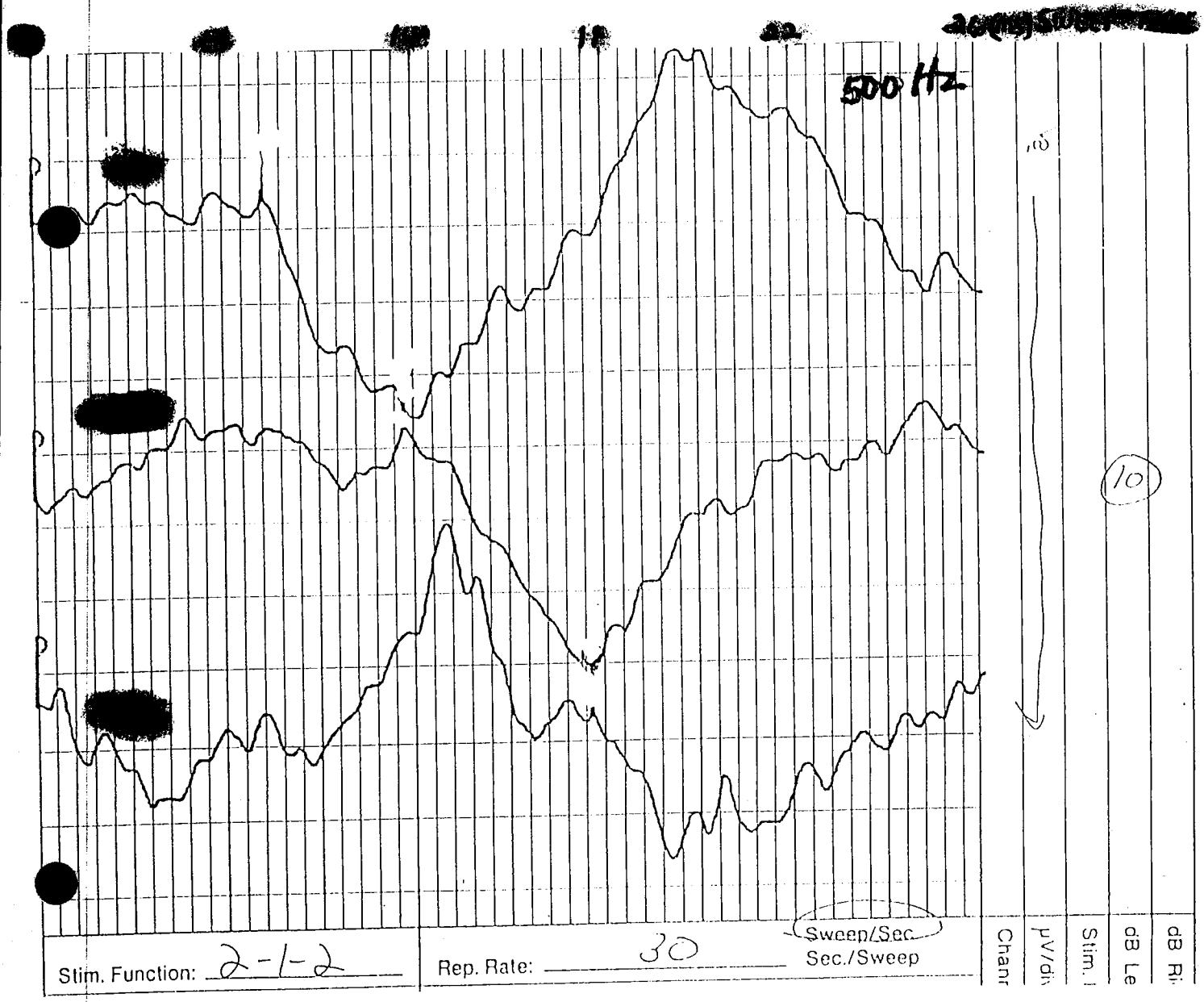
3. There is a greater shift in latency with decreased intensity relative to Wave V.

Sample sets of traces for 2000 Hz and 500 Hz were provided to the students. (See attached traces) Students also interpolated thresholds for several sets of traces during the instruction period.

[redacted]

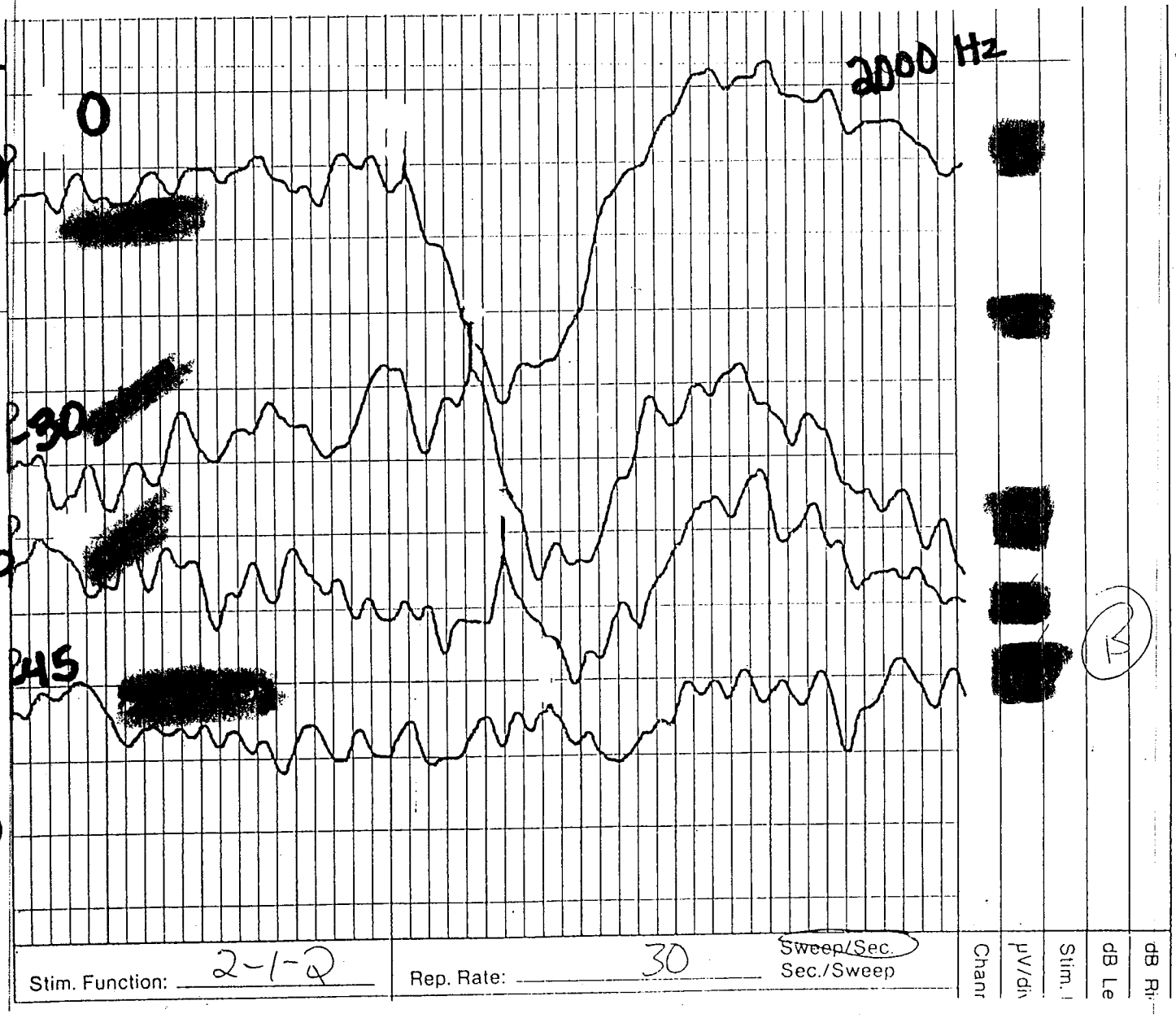
B. Center Frequency of Test Stimulus

[redacted]



D. Number of Accepted Sweeps (2000 unless specified otherwise, for eg. 1200)

[redacted]



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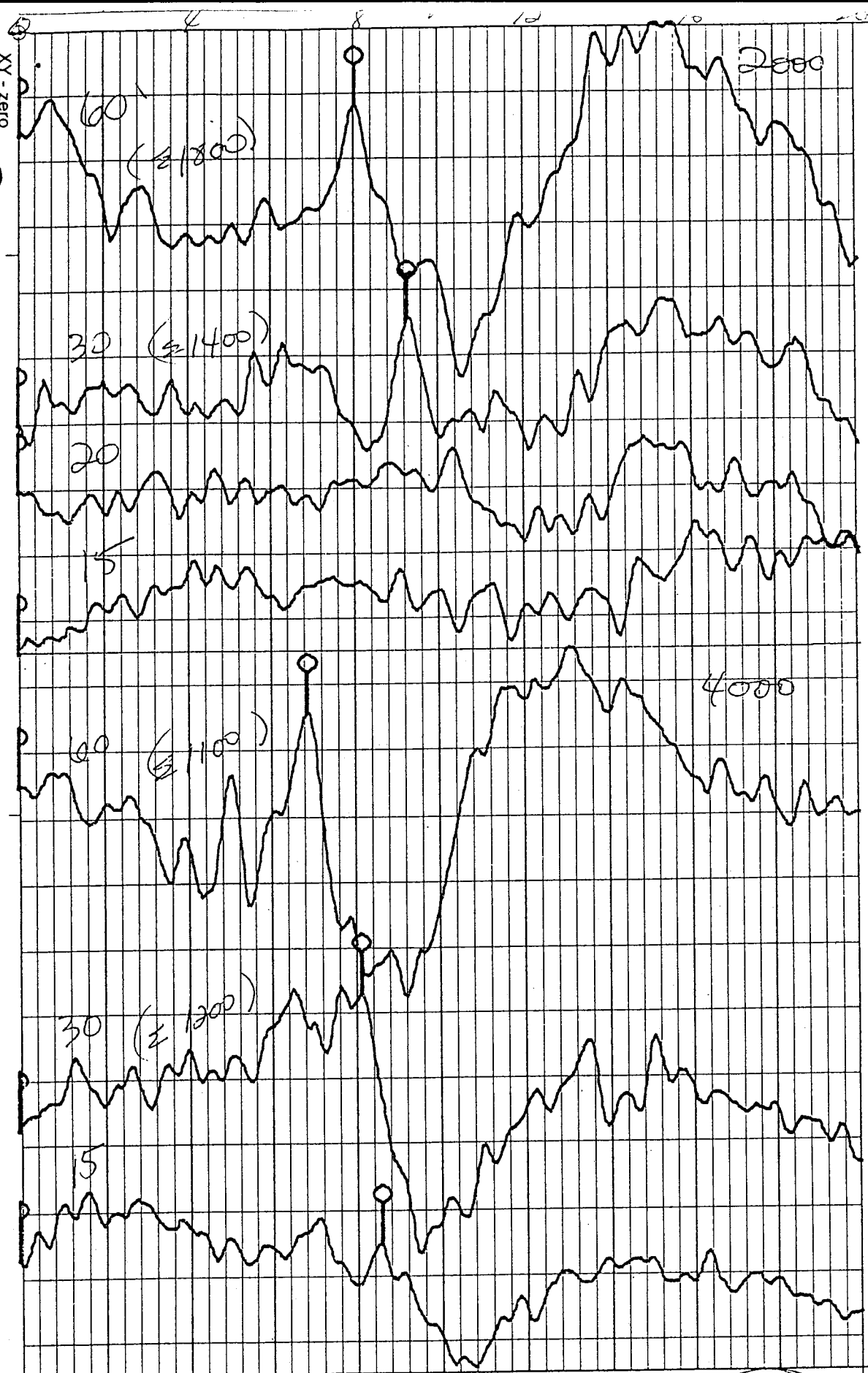
Experimental Parameters

		ABR 2000 Hz	ABR 500 Hz
(1)	Polarity	Rarefaction	Rarefaction
(2)	Stimulus Function	2-1-2 tone burst	2-1-2 tone bursts
(3)	Center Frequency	2000 Hz	500 Hz
(4)	Input Filter	Medium [Low Cut 48 High Cut 1539]	Medium
(5)	Output Polarity	Fixed	Fixed
(6)	# Sweeps	2000 (unless specified otherwise)	2000 (unless specified otherwise)
(7)	Delay Δt (MSEC)	0 msec	6 msec
(8)	Window	20 msec	20 msec
(9)	Repetition Rate	30 sweeps/sec	30 sweeps/sec



Samples Given To Students

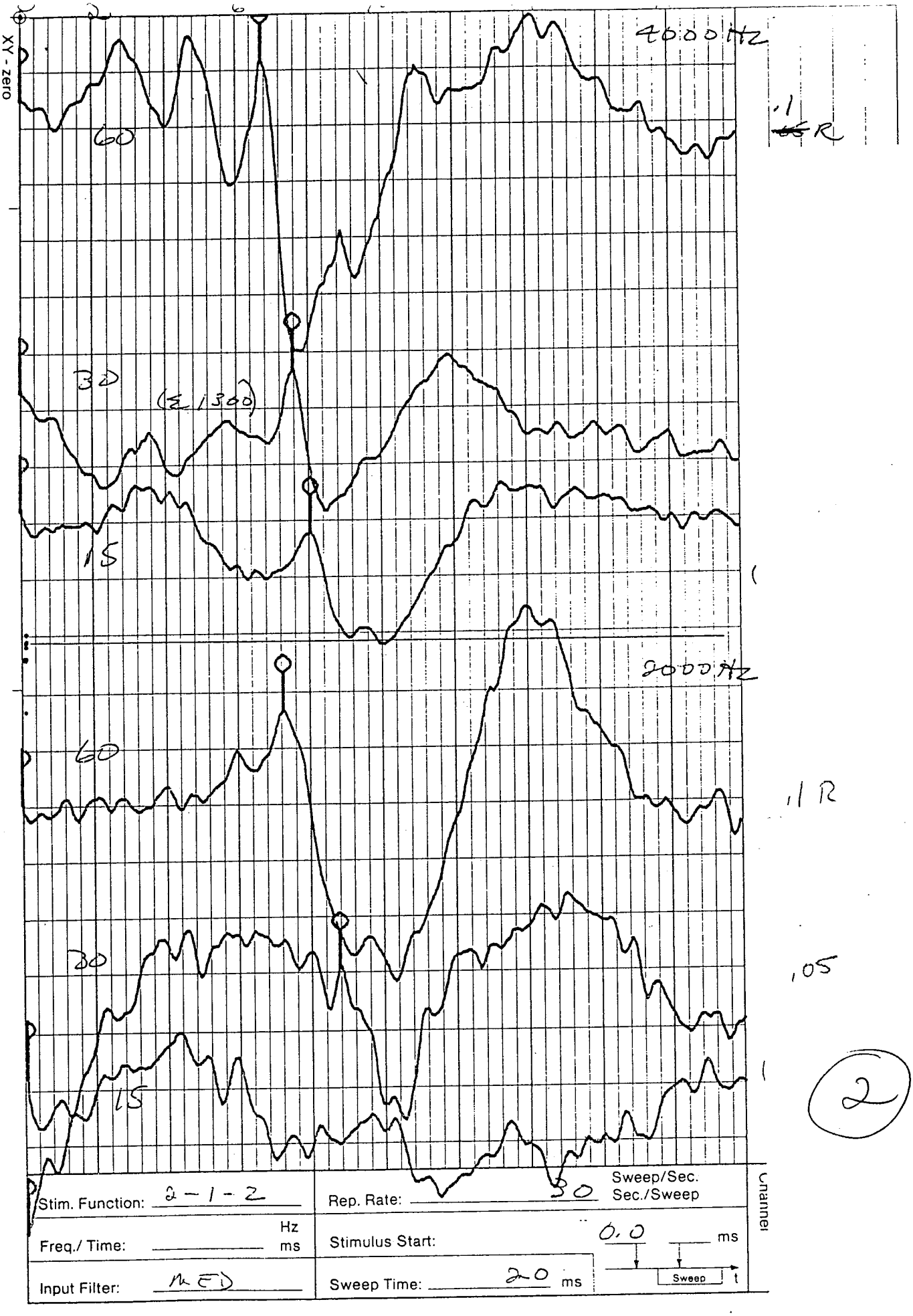
1

Stim. Function: 2-1-2	Rep. Rate: 30 Sweep/Sec. Sec./Sweep	Channel	dB Right / dB Left Intens.
Freq./ Time: ____ Hz ms	Stimulus Start: 0.0 ms	μV/div. Scaling	Stim. Polarity
Input Filter: Pulse	Sweep Time: 20 ms		

Sweep t

Size: Expand.

Order No. 7 - 16 - 01771



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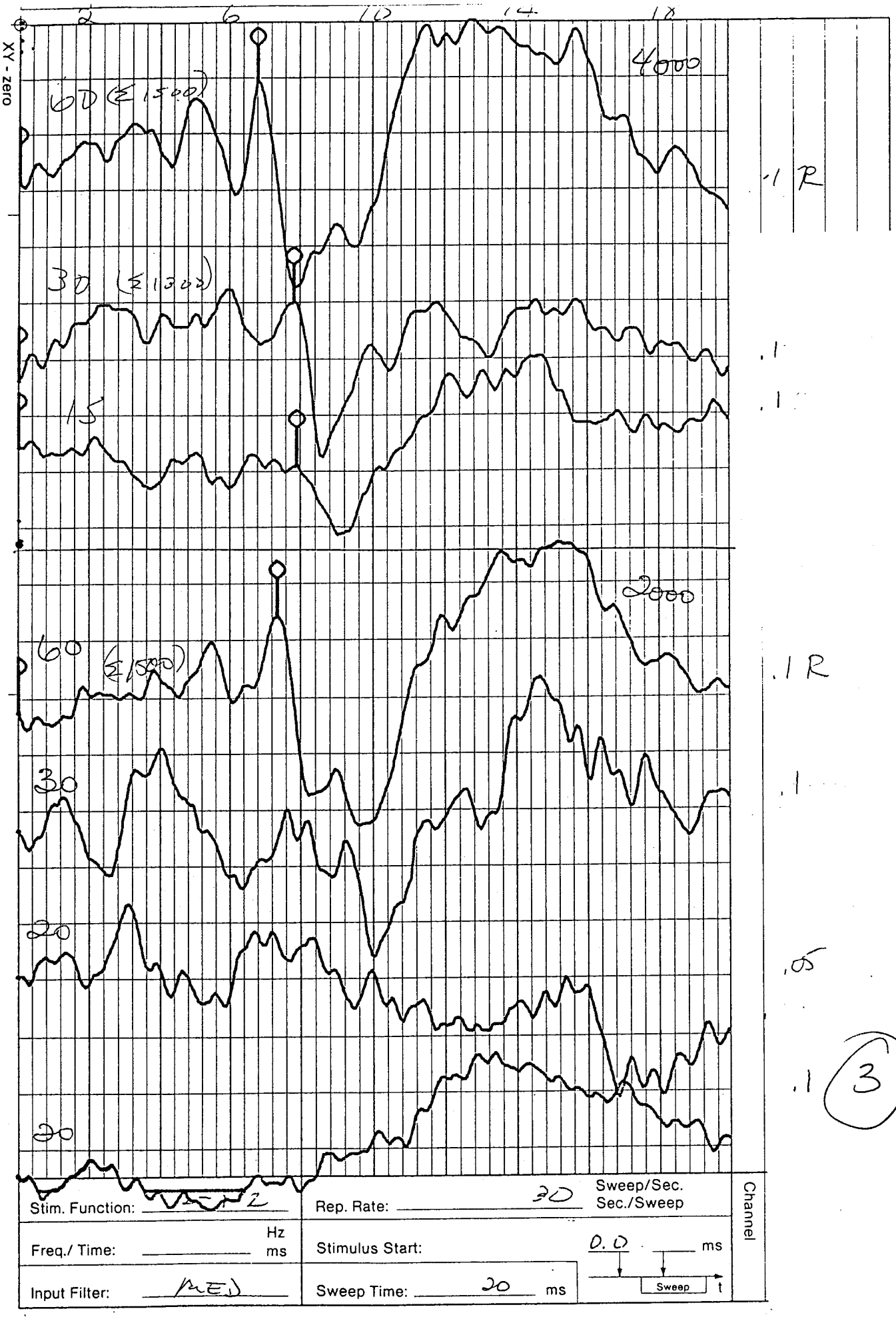
(2)



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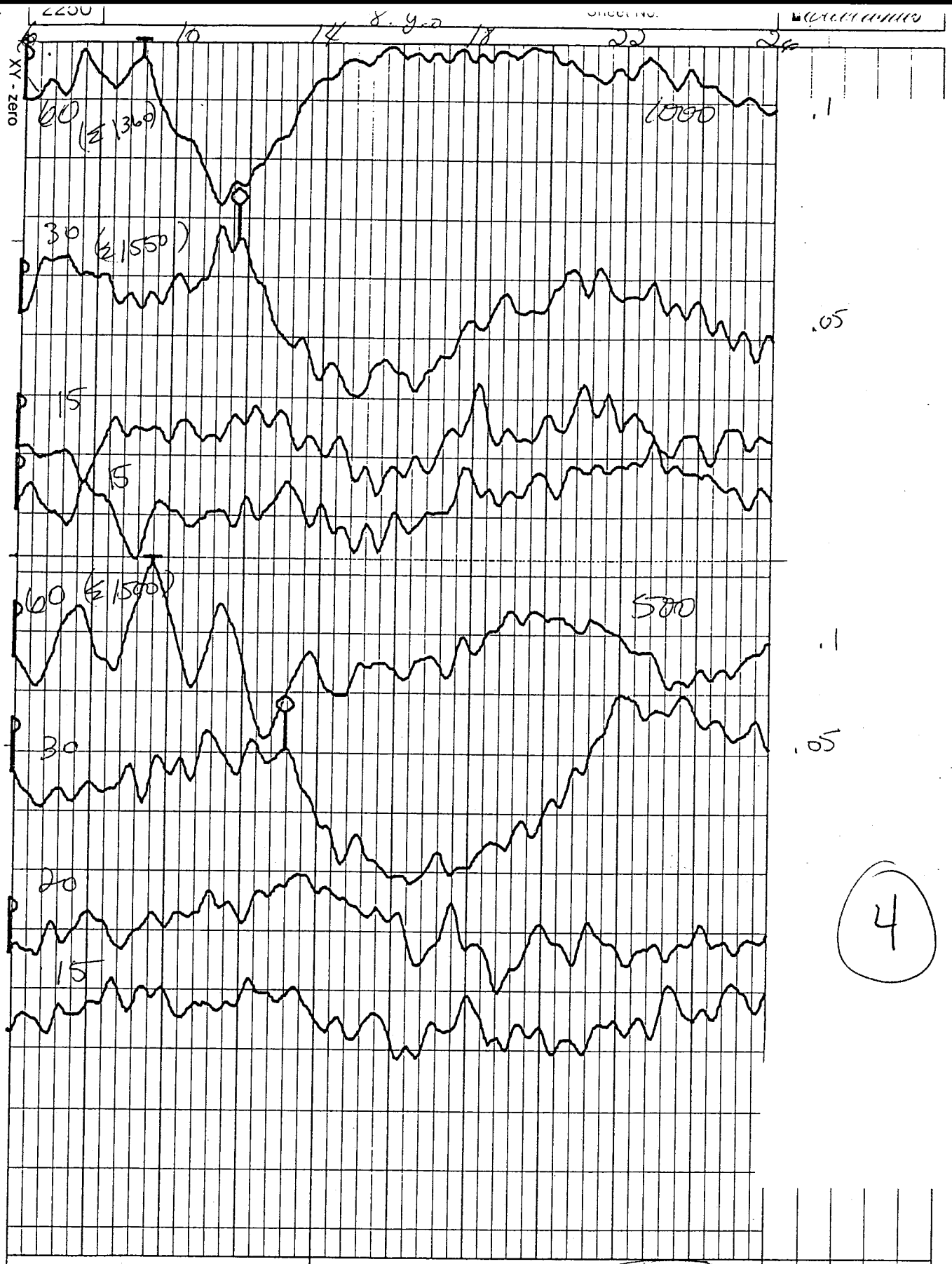

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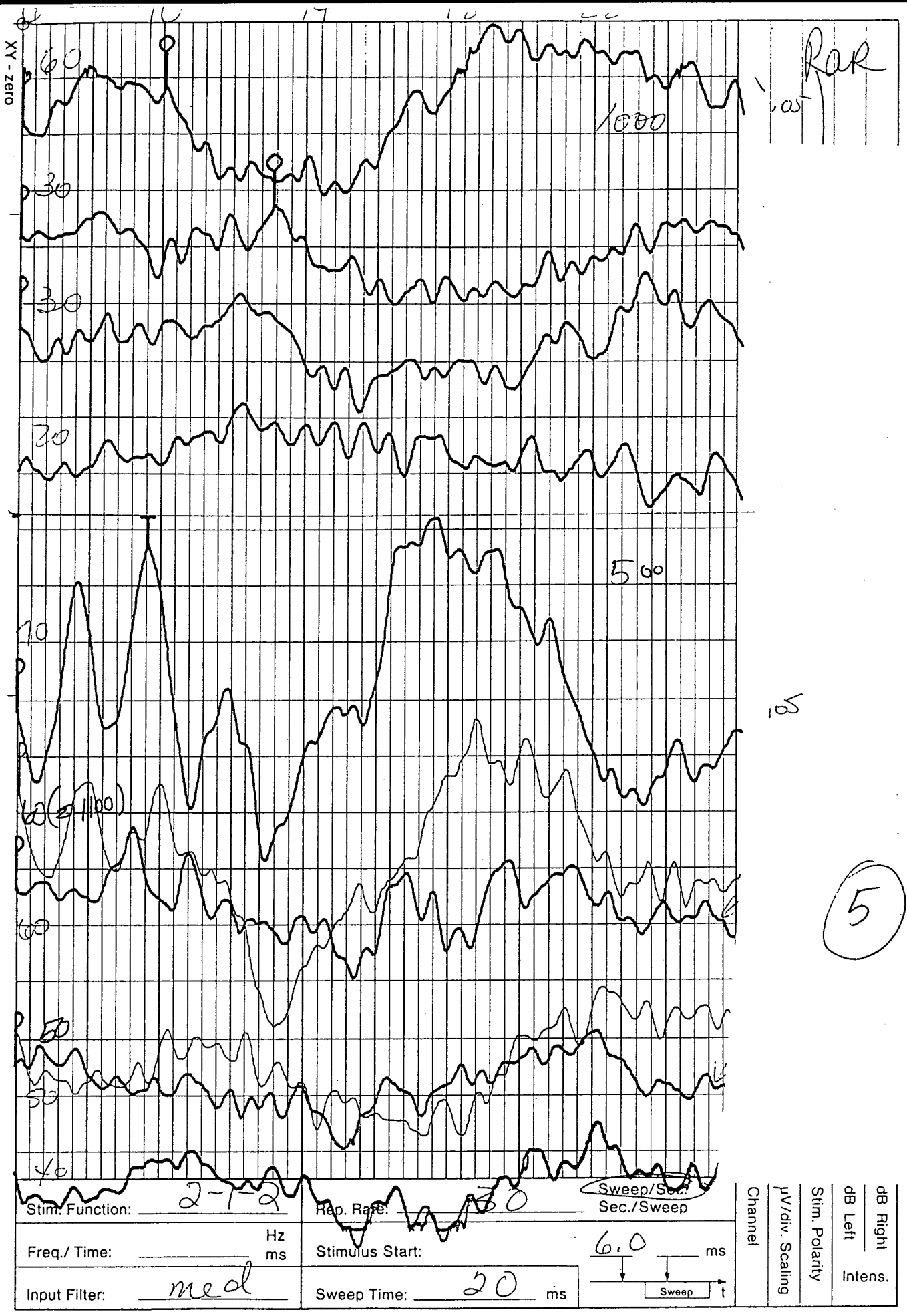
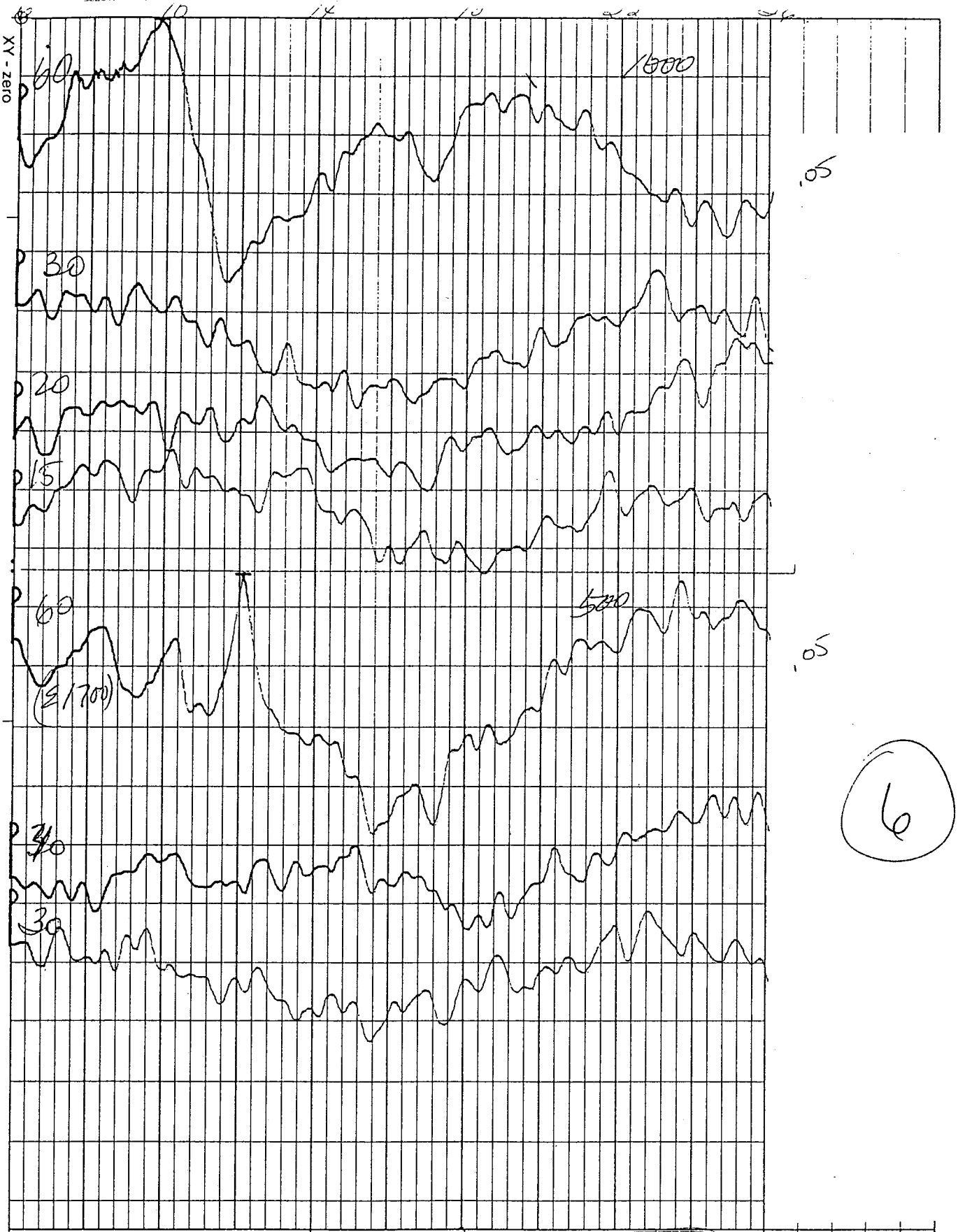
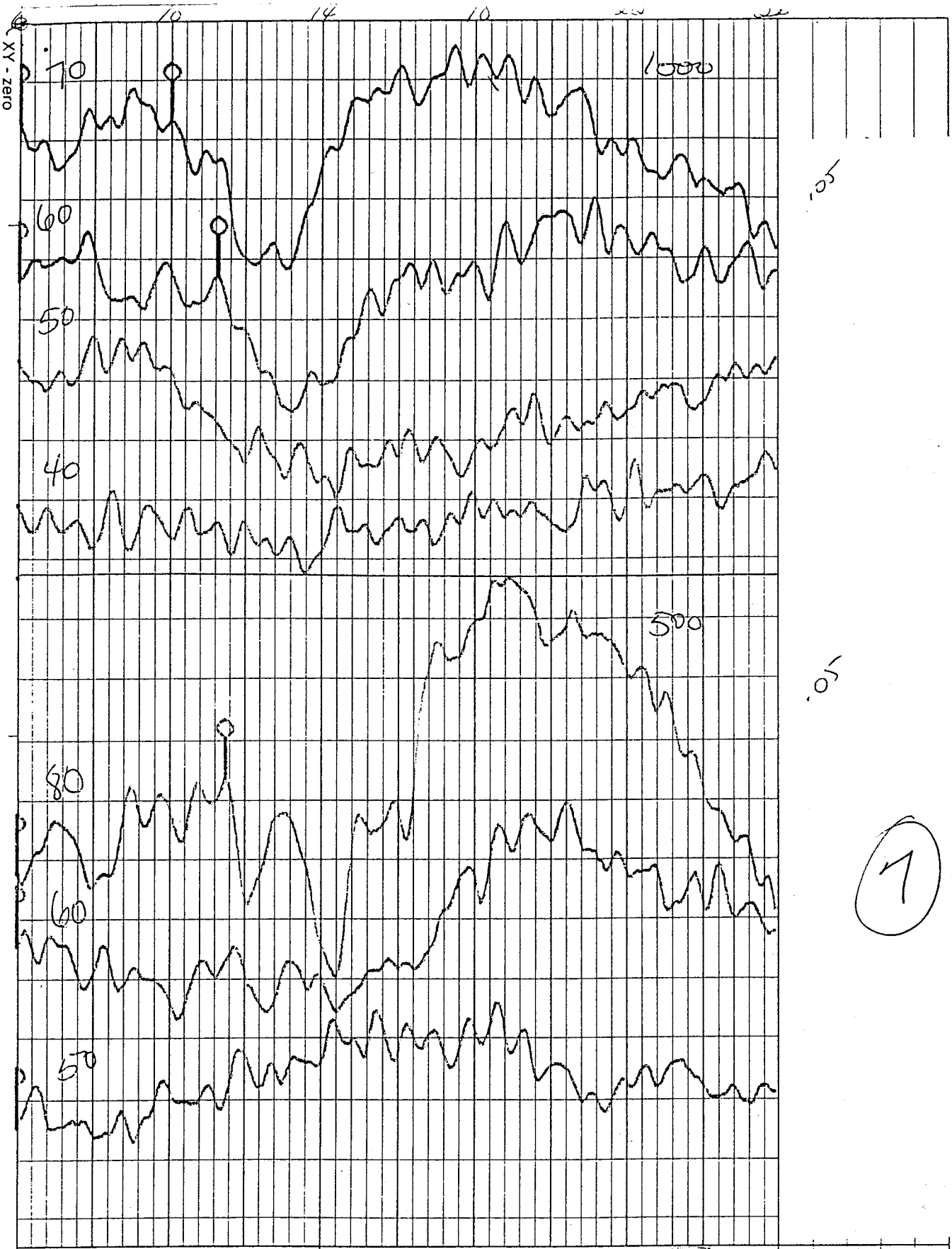
Stim. Function: 2-1-2	Rep. Rate: 30 Sweep/Sec. Sec./Sweep	Channel			dB Right
Freq./ Time: Hz ms	Stimulus Start: 6.0 ms	μV/div. Scaling		dB Left	
Input Filter: Rect	Sweep Time: 20 ms	Stim. Polarity		Intens.	


XY - zero
60
30
30
30
1000
RAR
1.05
560
10
60 (2 1100)
60
60
50
40
5
Size: Expand.
Stim. Function: 2-1-2
Rep. Rate:
Sweep/Sec.
Sec./Sweep
Freq./ Time: Hz ms
Stimulus Start: 6.0 ms
Input Filter: med
Sweep Time: 20 ms
Sweep
t
Channel
μV/div. Scaling
Stim. Polarity
dB Right
dB Left
Intens.



Stim. Function: 2-1-2	Rep. Rate: 30 Sweep/Sec. Sec./Sweep	Channel	dB Right / dB Left Intens.
Freq./ Time: ____ Hz ms	Stimulus Start: 6.0 ms	μV/div. Scaling	
Input Filter: Fixed	Sweep Time: 20 ms	Stim. Polarity	

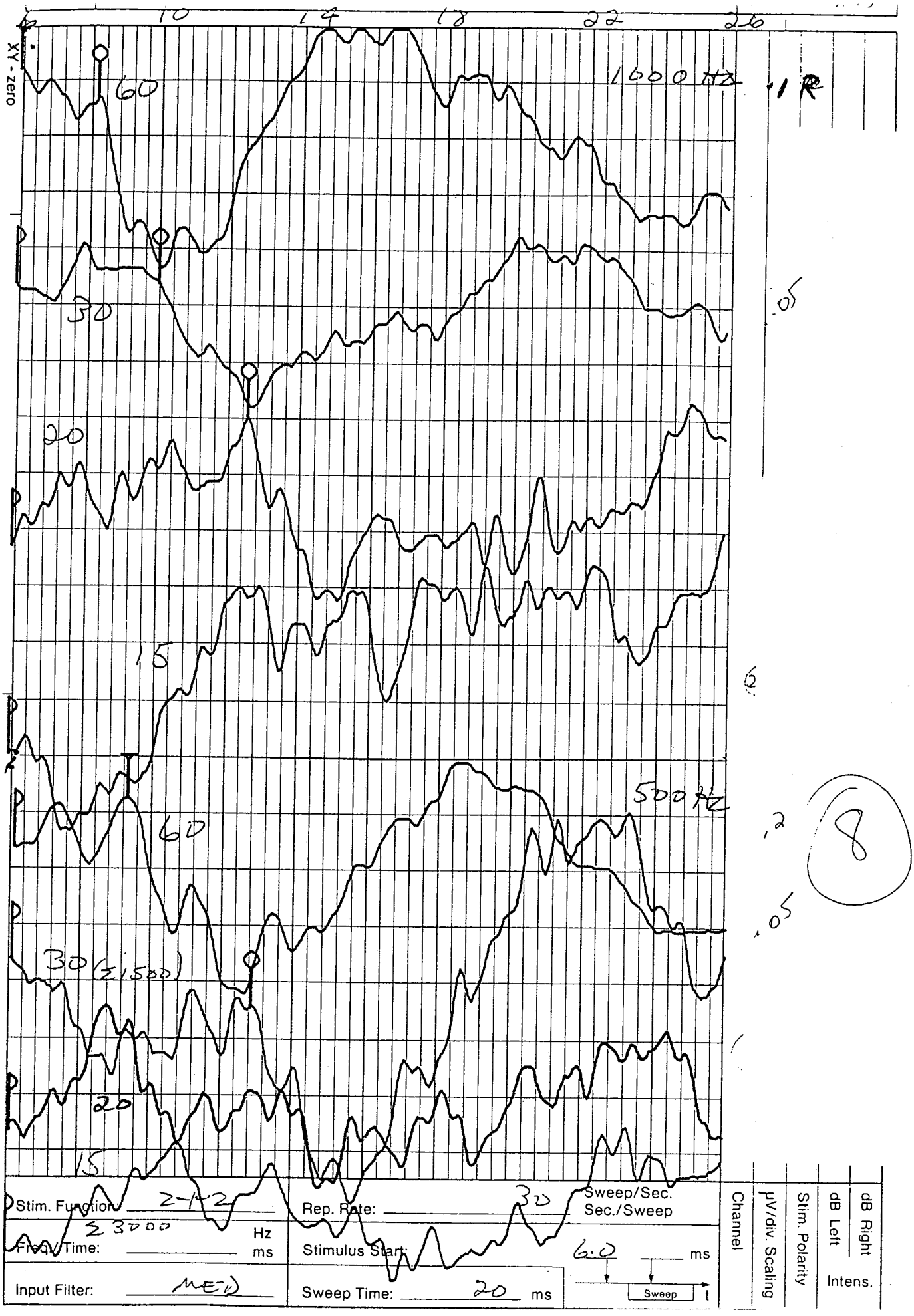
Sweep t



Stim. Function: 2-/-2	Rep. Rate: 30 Sweep/Sec Sec./Sweep	Channel	dB Right / dB Left Intens.
Freq./ Time: ____ Hz ms	Stimulus Start: 6.0 ms (Sweep t)	μV/div. Scaling	Stim. Polarity
Input Filter: Band	Sweep Time: 20 ms		

Size: Expand.

Order No 7 - 16 - 0171



Size: Expand.

Order No 7 - 16 - 0171

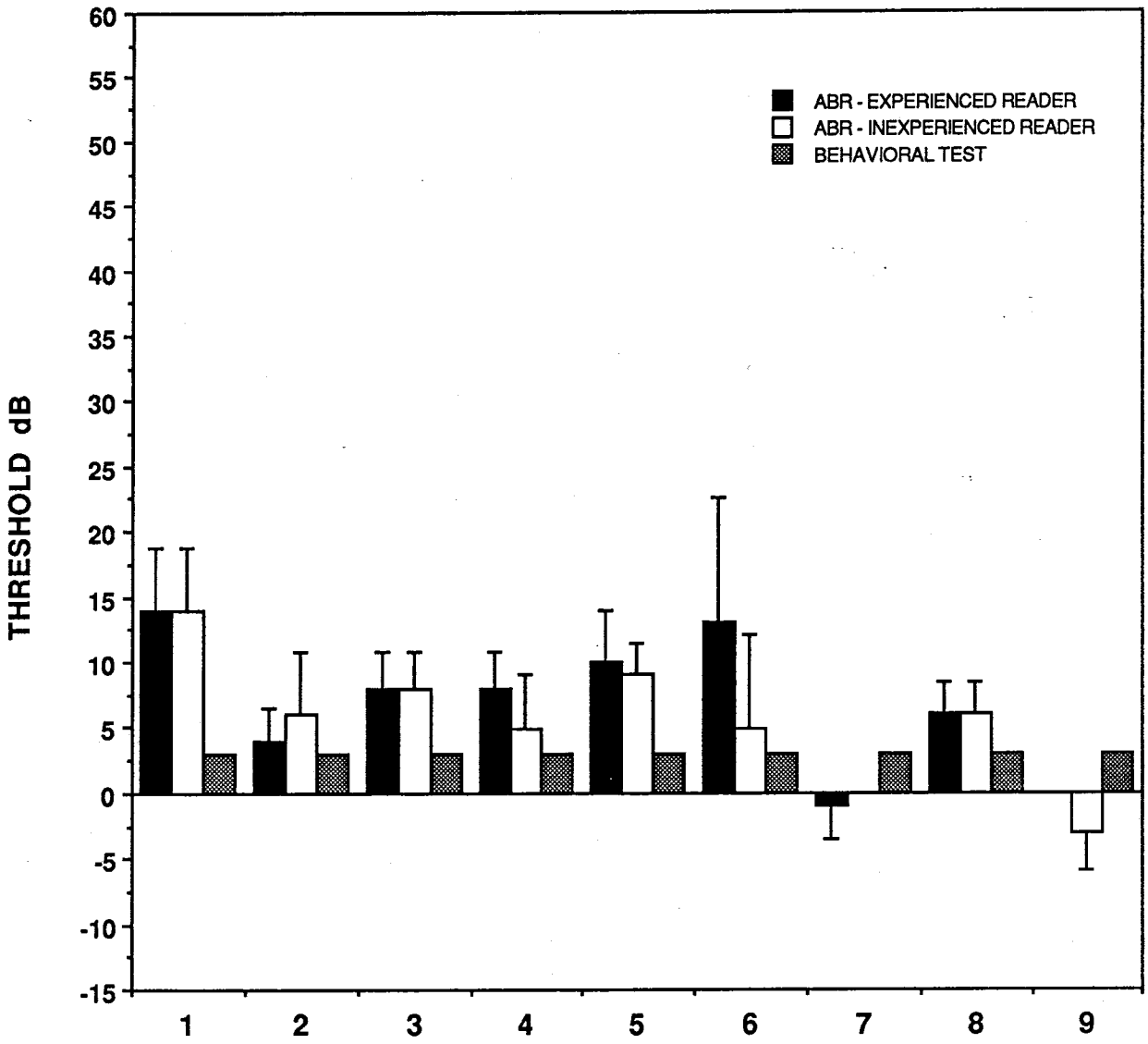
Appendix B

2000 Hz Mean Threshold Estimates

For Subjects #1 thru #8 Across Each Session

Note: Vertical lines are shown for one standard deviation. At times, the standard deviation equals zero and no vertical lines are present.

2000 Hz THRESHOLD ESTIMATES FOR SUBJECT 1

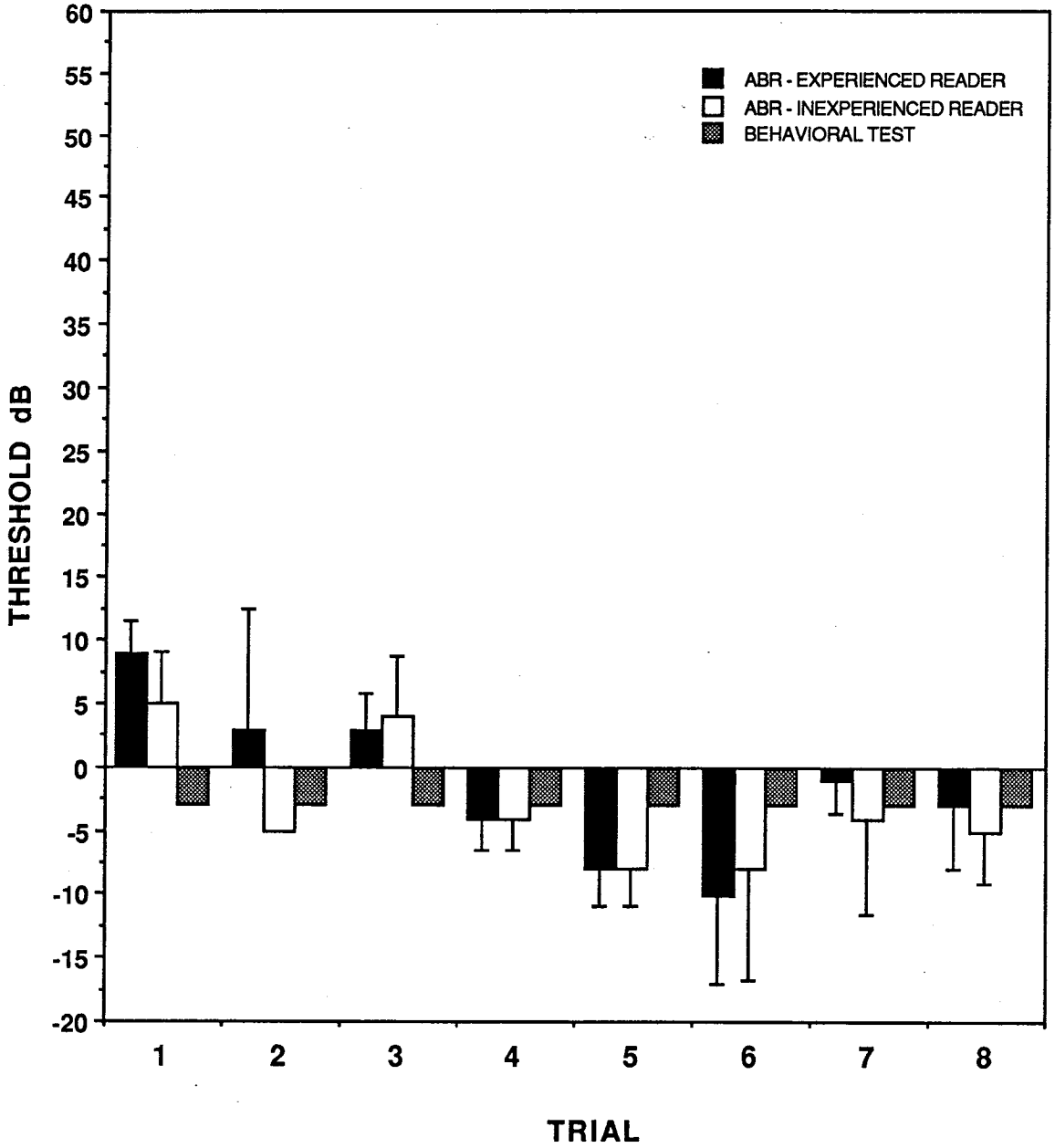


BLACK REPRESENTS THE MEAN OF THE 2000 Hz THRESHOLD ESTIMATES BY EXPERIENCED READERS

WHITE REPRESENTS THE MEAN OF THE 2000 Hz THRESHOLD ESTIMATES BY INEXPERIENCED READERS

SHADED REPRESENTS MEAN BEHAVIORAL THRESHOLD ACROSS SESSIONS FOR SUBJECT #1

2000 Hz THRESHOLD ESTIMATE FOR SUBJECT 2

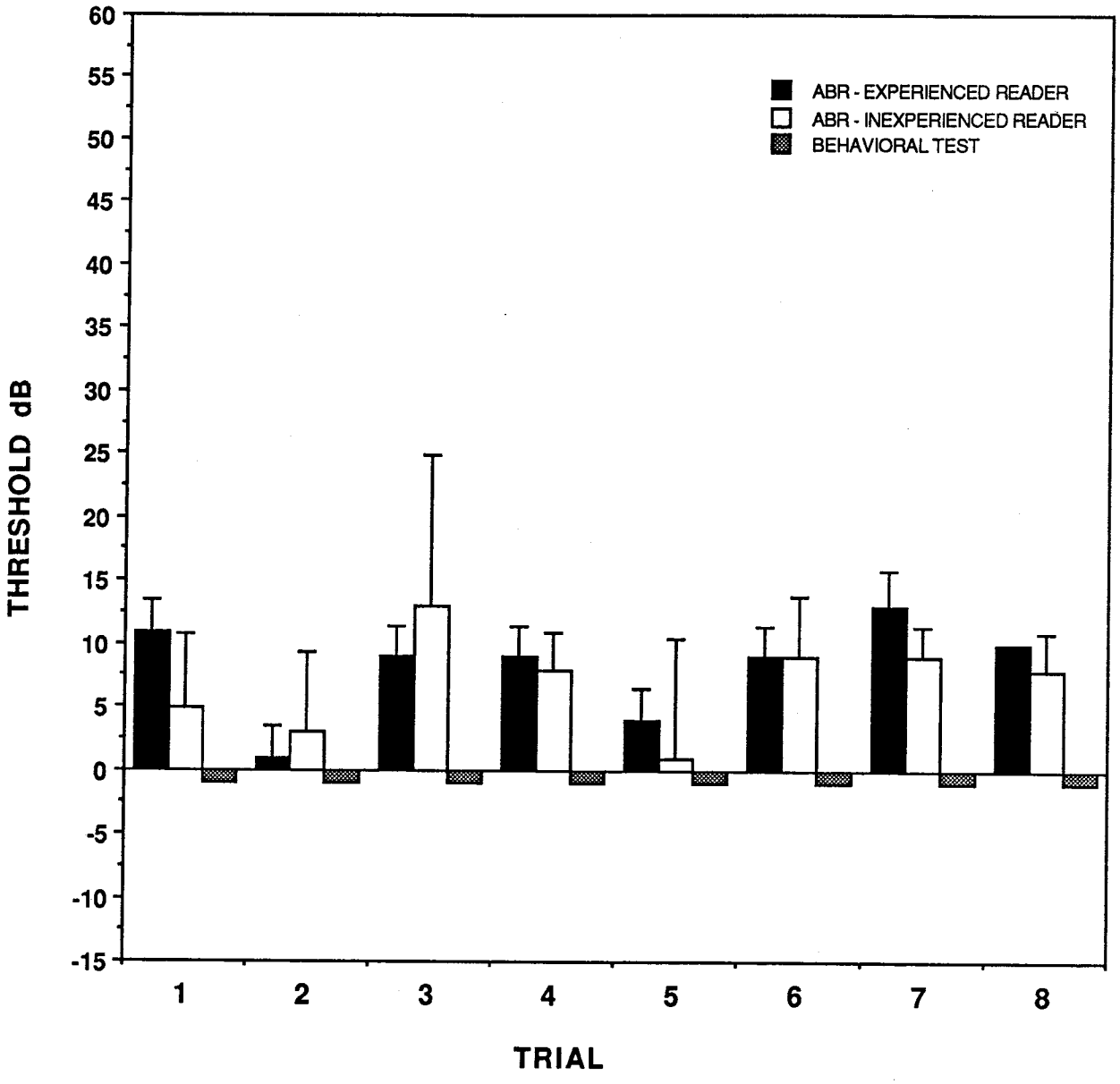


BLACK REPRESENTS THE MEAN OF THE 2000 Hz THRESHOLD ESTIMATES BY EXPERIENCED READERS

WHITE REPRESENTS THE MEAN OF THE 2000 Hz THRESHOLD ESTIMATES BY INEXPERIENCED READERS

SHADED REPRESENTS MEAN BEHAVIORAL THRESHOLD ACROSS SESSIONS FOR SUBJECT #2

2000 Hz THRESHOLD ESTIMATES FOR SUBJECT 3

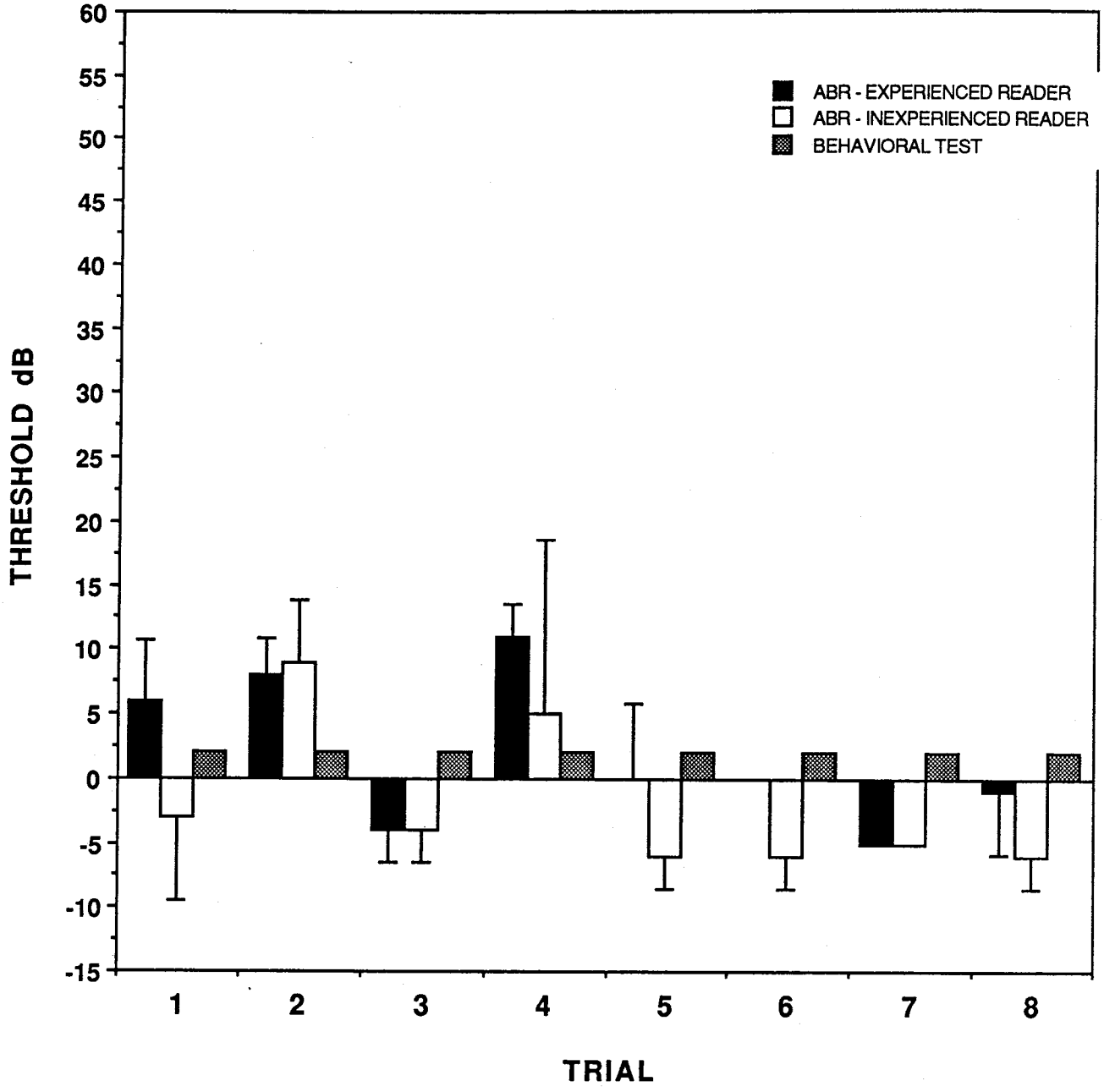


BLACK REPRESENTS THE MEAN OF THE 2000 Hz THRESHOLD ESTIMATES BY EXPERIENCED READERS

WHITE REPRESENTS THE MEAN OF THE 2000 Hz THRESHOLD ESTIMATES BY INEXPERIENCED READERS

SHADED REPRESENTS MEAN BEHAVIORAL THRESHOLD ACROSS SESSIONS FOR SUBJECT #3

2000 Hz THRESHOLD ESTIMATES FOR SUBJECT 4

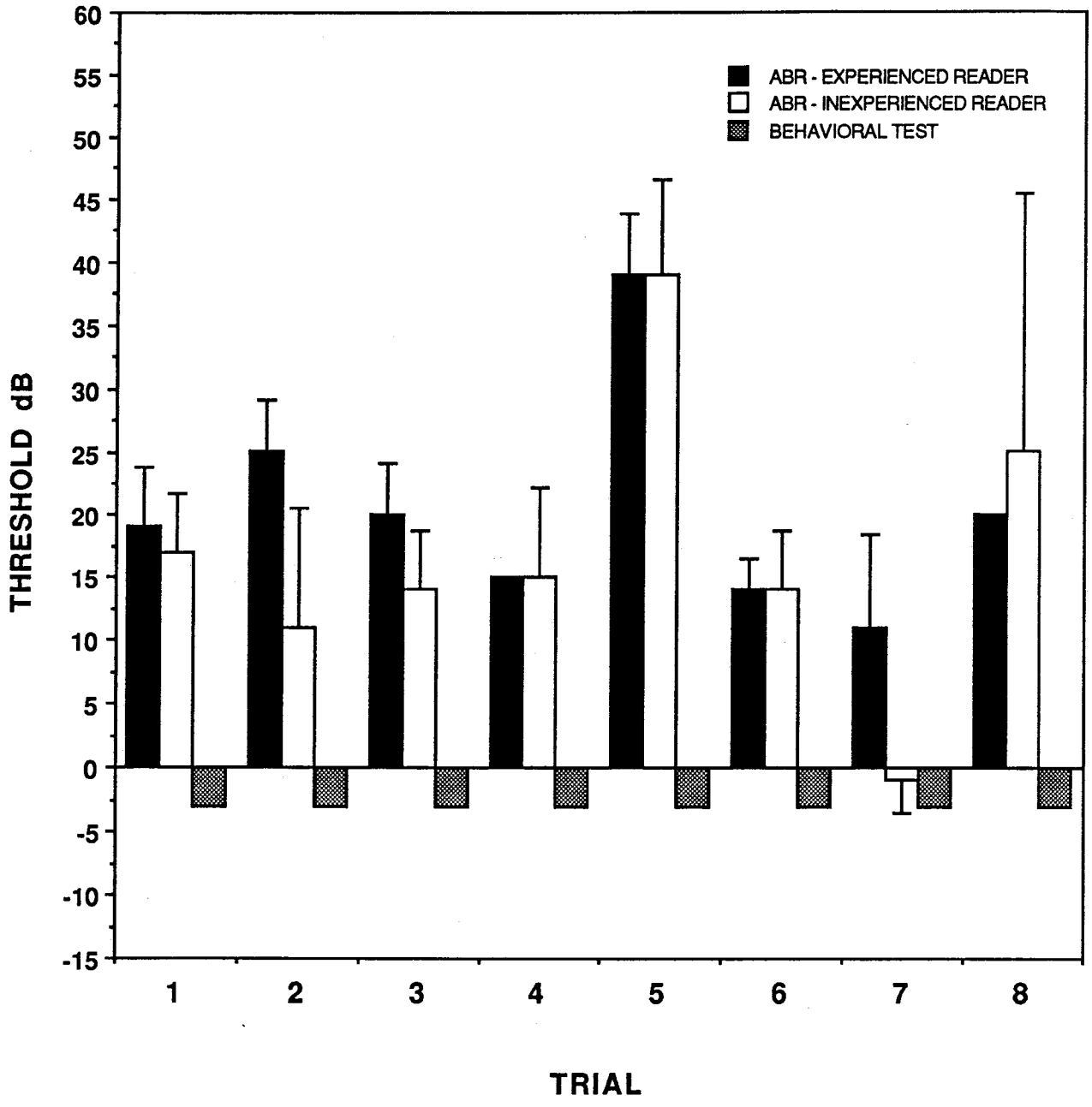


BLACK REPRESENTS THE MEAN OF THE 2000 Hz THRESHOLD ESTIMATES BY EXPERIENCED READERS

WHITE REPRESENTS THE MEAN OF THE 2000 Hz THRESHOLD ESTIMATES BY INEXPERIENCED READERS

SHADED REPRESENTS MEAN BEHAVIORAL THRESHOLD ACROSS SESSIONS FOR SUBJECT #4

2000 Hz THRESHOLD ESTIMATES FOR SUBJECT 5

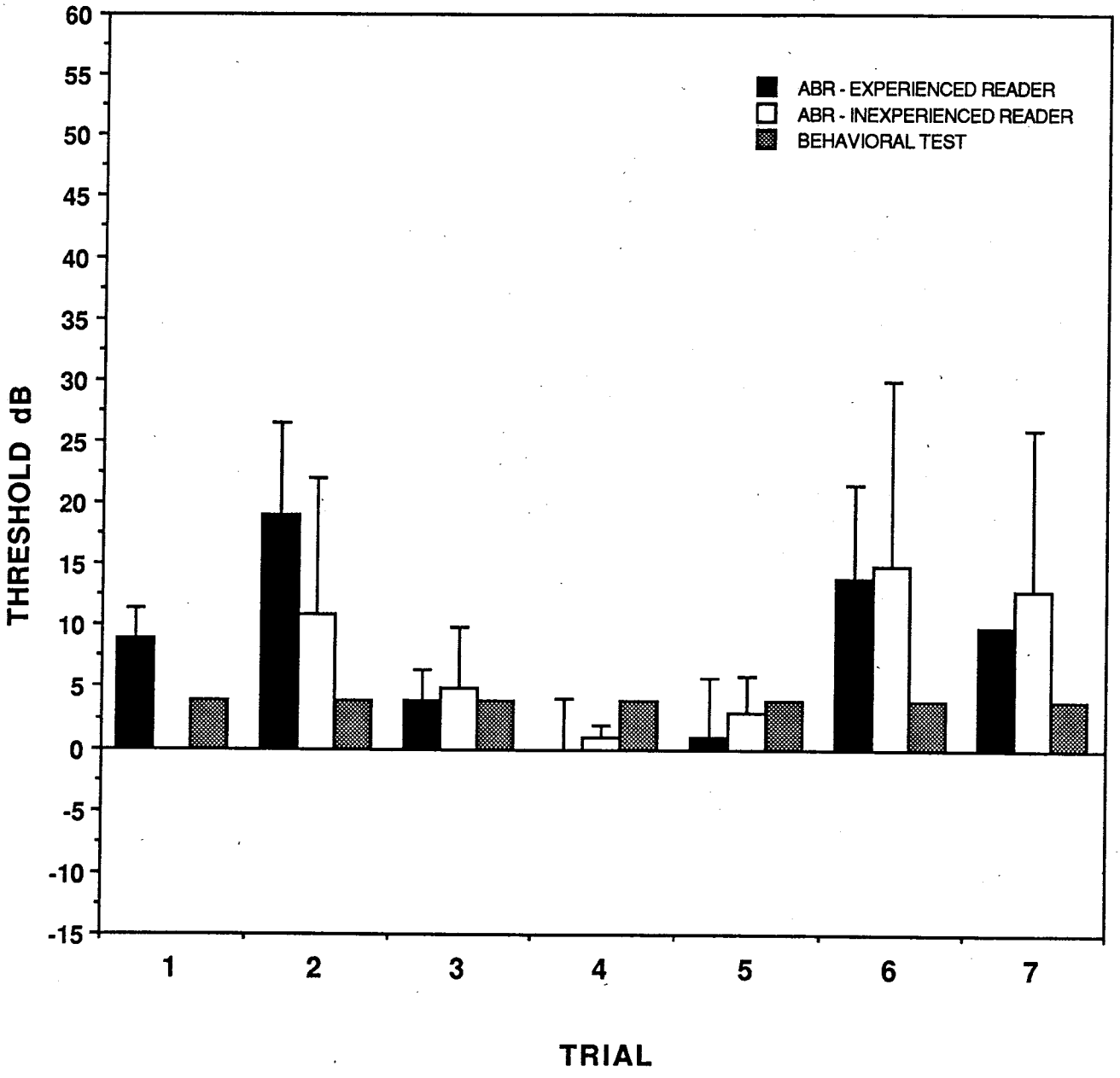


BLACK REPRESENTS THE MEAN OF THE 2000 Hz THRESHOLD ESTIMATES BY EXPERIENCED READERS

WHITE REPRESENTS THE MEAN OF THE 2000 Hz THRESHOLD ESTIMATES BY INEXPERIENCED READERS

SHADED REPRESENTS MEAN BEHAVIORAL THRESHOLD ACROSS SESSIONS FOR SUBJECT #5

2000 Hz THRESHOLD ESTIMATES FOR SUBJECT 6

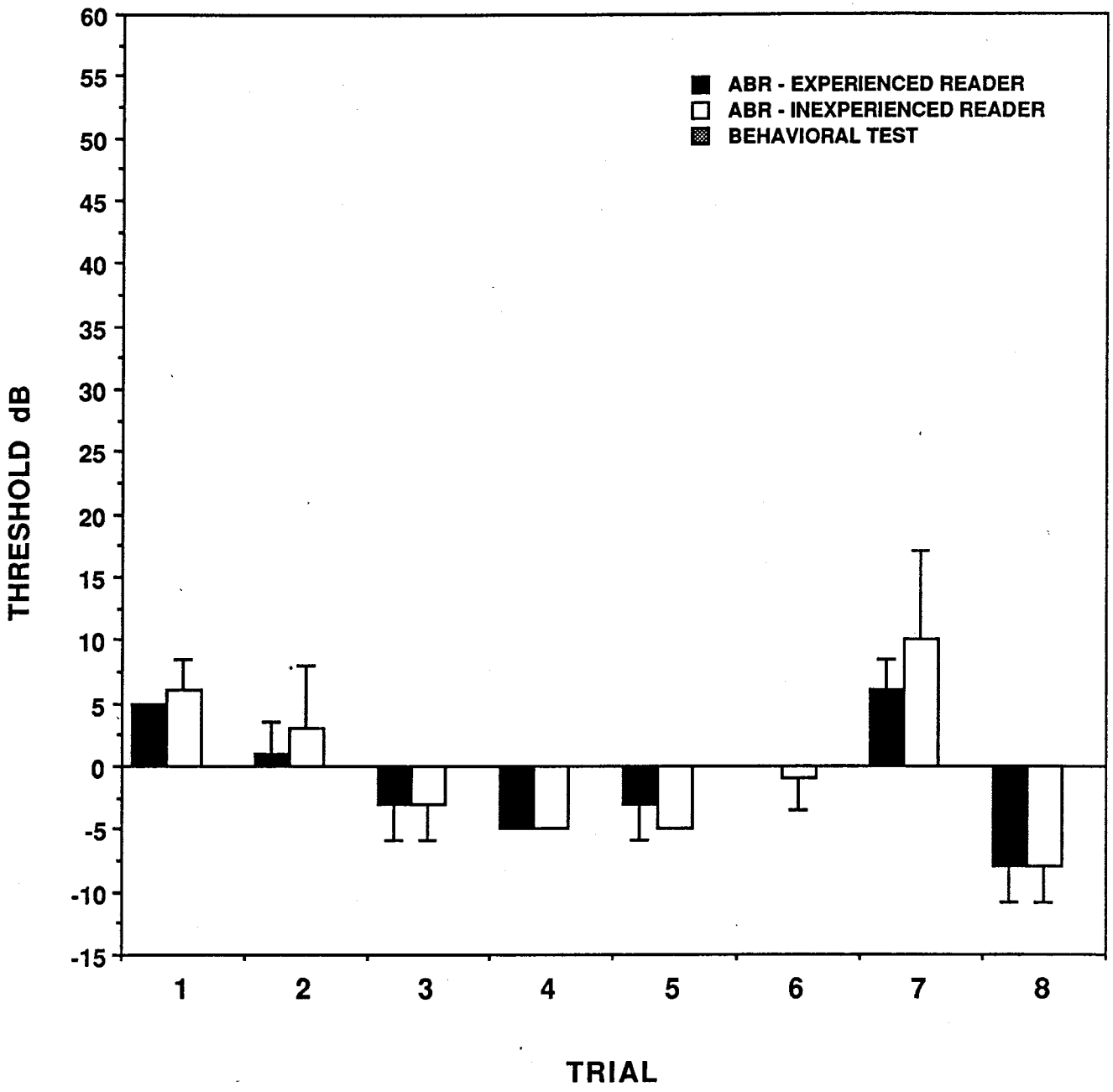


BLACK REPRESENTS THE MEAN OF THE 2000 Hz THRESHOLD ESTIMATES BY EXPERIENCED READERS

WHITE REPRESENTS THE MEAN OF THE 2000 Hz THRESHOLD ESTIMATES BY INEXPERIENCED READERS

SHADED REPRESENTS MEAN BEHAVIORAL THRESHOLD ACROSS SESSIONS FOR SUBJECT #6

2000 Hz THRESHOLD ESTIMATES FOR SUBJECT 7

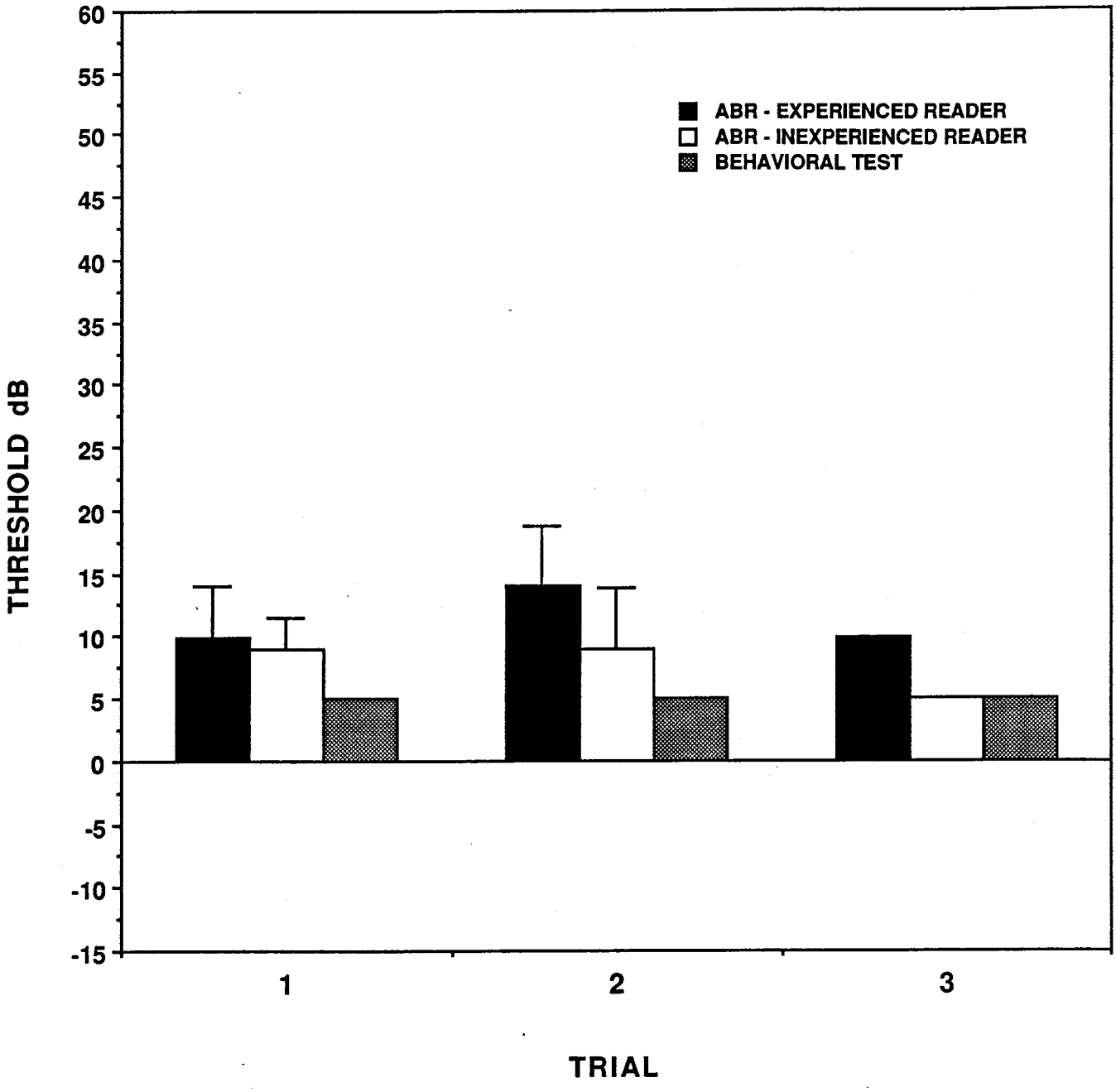


BLACK REPRESENTS THE MEAN OF THE 2000 Hz THRESHOLD ESTIMATES BY EXPERIENCED READERS

WHITE REPRESENTS THE MEAN OF THE 2000 Hz THRESHOLD ESTIMATES BY INEXPERIENCED READERS

SHADED REPRESENTS MEAN BEHAVIORAL THRESHOLD ACROSS SESSIONS FOR SUBJECT #7

2000 Hz THRESHOLD ESTIMATES FOR SUBJECT 8



BLACK REPRESENTS THE MEAN OF THE 2000 Hz THRESHOLD ESTIMATES BY EXPERIENCED READERS

WHITE REPRESENTS THE MEAN OF THE 2000 Hz THRESHOLD ESTIMATES BY INEXPERIENCED READERS

SHADED REPRESENTS MEAN BEHAVIORAL THRESHOLD ACROSS SESSIONS FOR SUBJECT #8

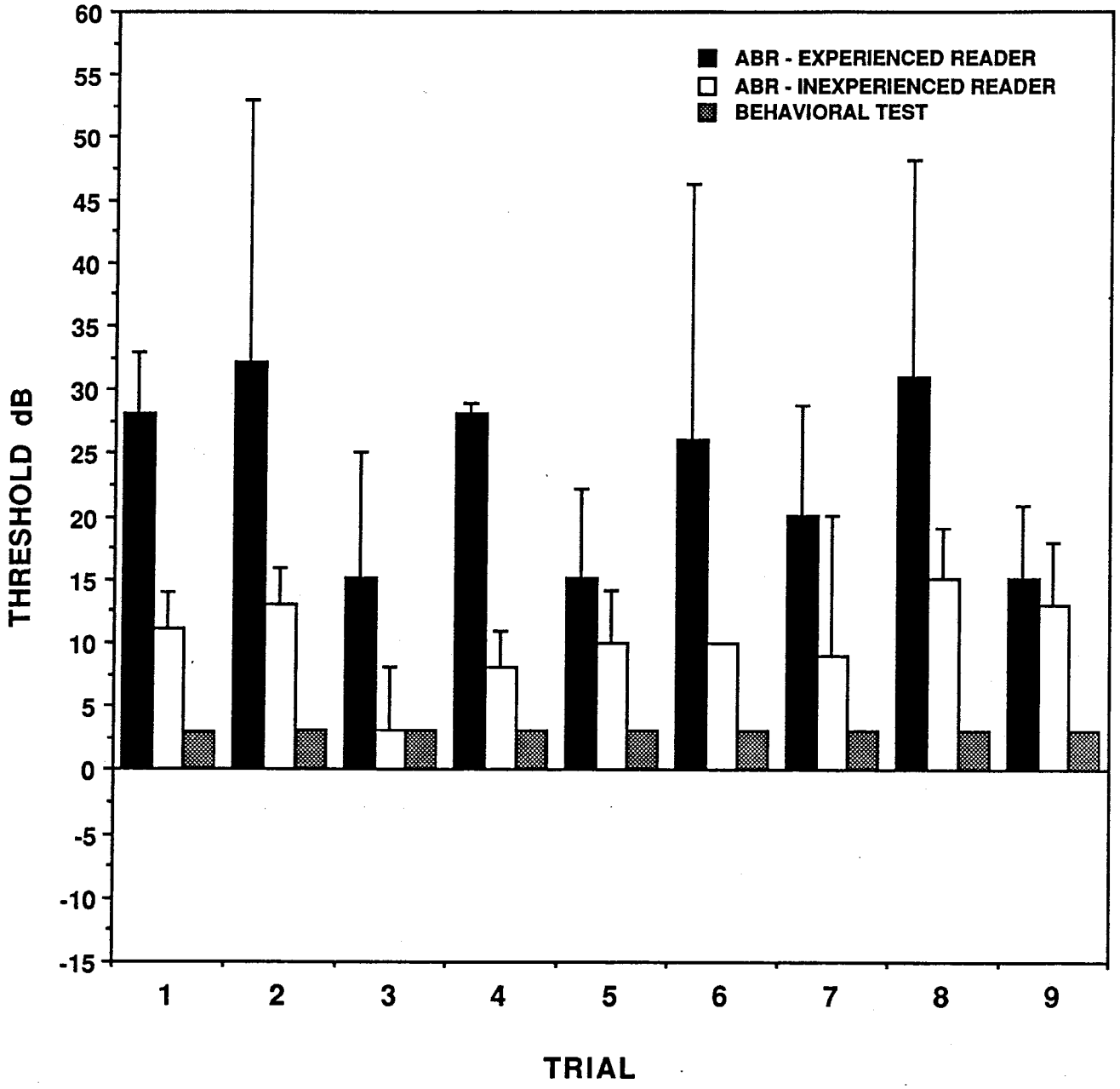
Appendix C

500 Hz SN10 Mean Threshold Estimates

For Subjects #1 thru #8 Across Each Session

Note: Vertical lines are shown for one standard deviation. At times, the standard deviation equals zero and no vertical lines are present.

500 Hz THRESHOLD ESTIMATES FOR SUBJECT 1

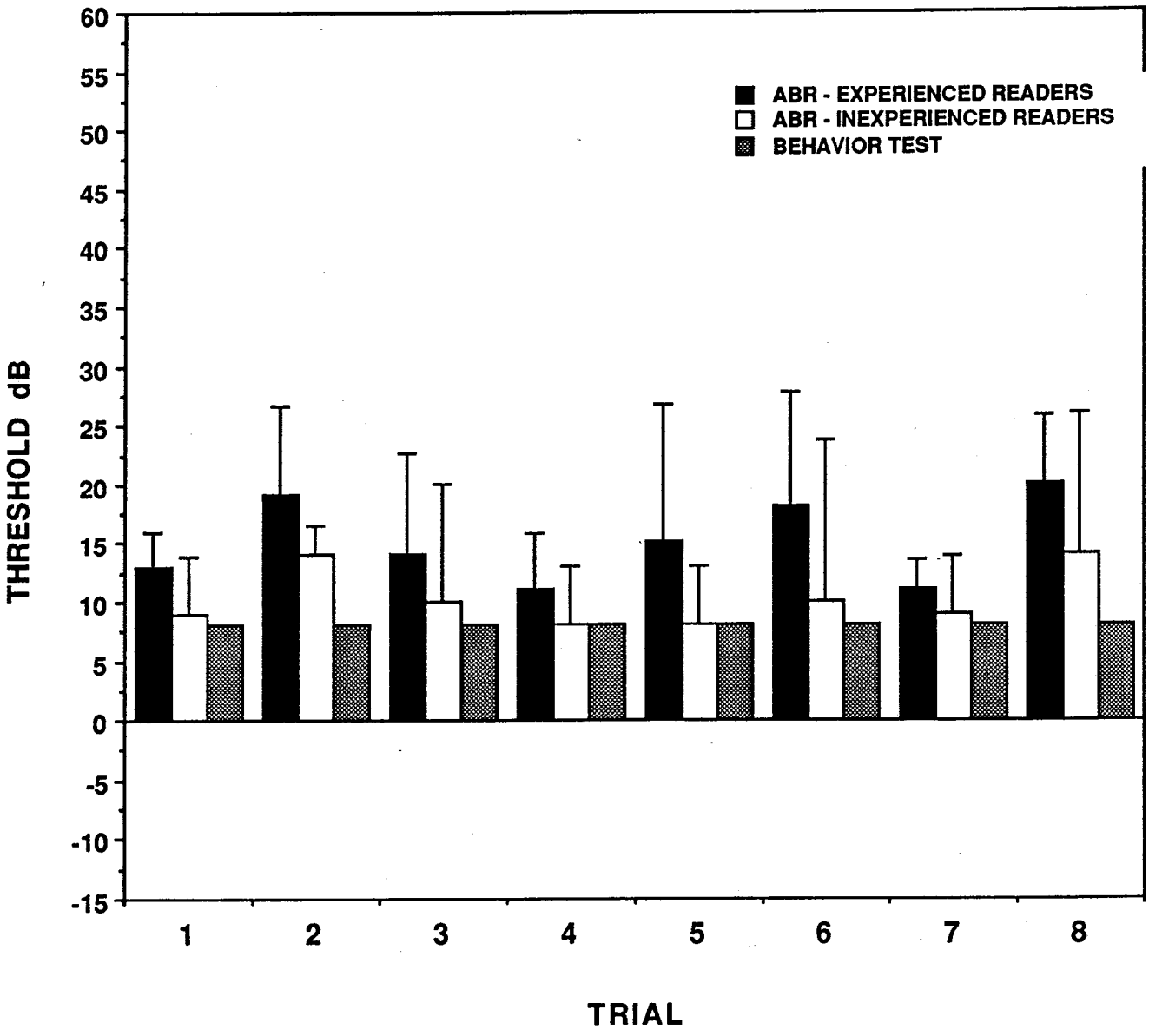


BLACK REPRESENTS THE MEAN OF THE 500 Hz SN10 THRESHOLD ESTIMATES BY EXPERIENCED READERS

WHITE REPRESENTS THE MEAN OF THE 500 Hz SN10 THRESHOLD ESTIMATES BY INEXPERIENCED READERS

SHADED REPRESENTS MEAN BEHAVIORAL THRESHOLD ACROSS SESSIONS FOR SUBJECT #1

500 Hz THRESHOLD ESTIMATES FOR SUBJECT 2

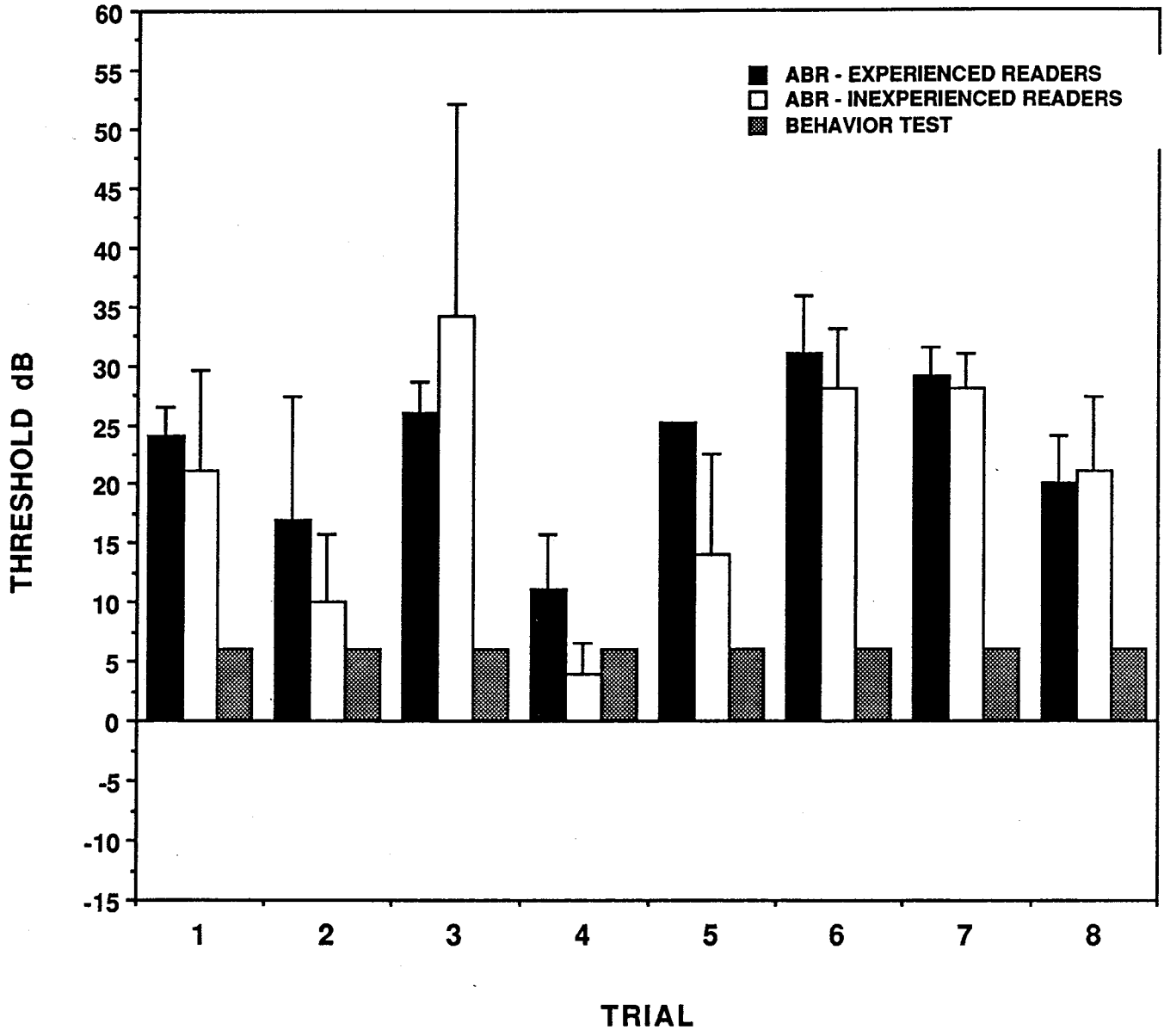


BLACK REPRESENTS THE MEAN OF THE 500 Hz SN10 THRESHOLD ESTIMATES BY EXPERIENCED READERS

WHITE REPRESENTS THE MEAN OF THE 500 Hz SN10 THRESHOLD ESTIMATES BY INEXPERIENCED READERS

SHADED REPRESENTS MEAN BEHAVIORAL THRESHOLD ACROSS SESSIONS FOR SUBJECT #2

500 Hz THRESHOLD ESTIMATES FOR SUBJECT 3

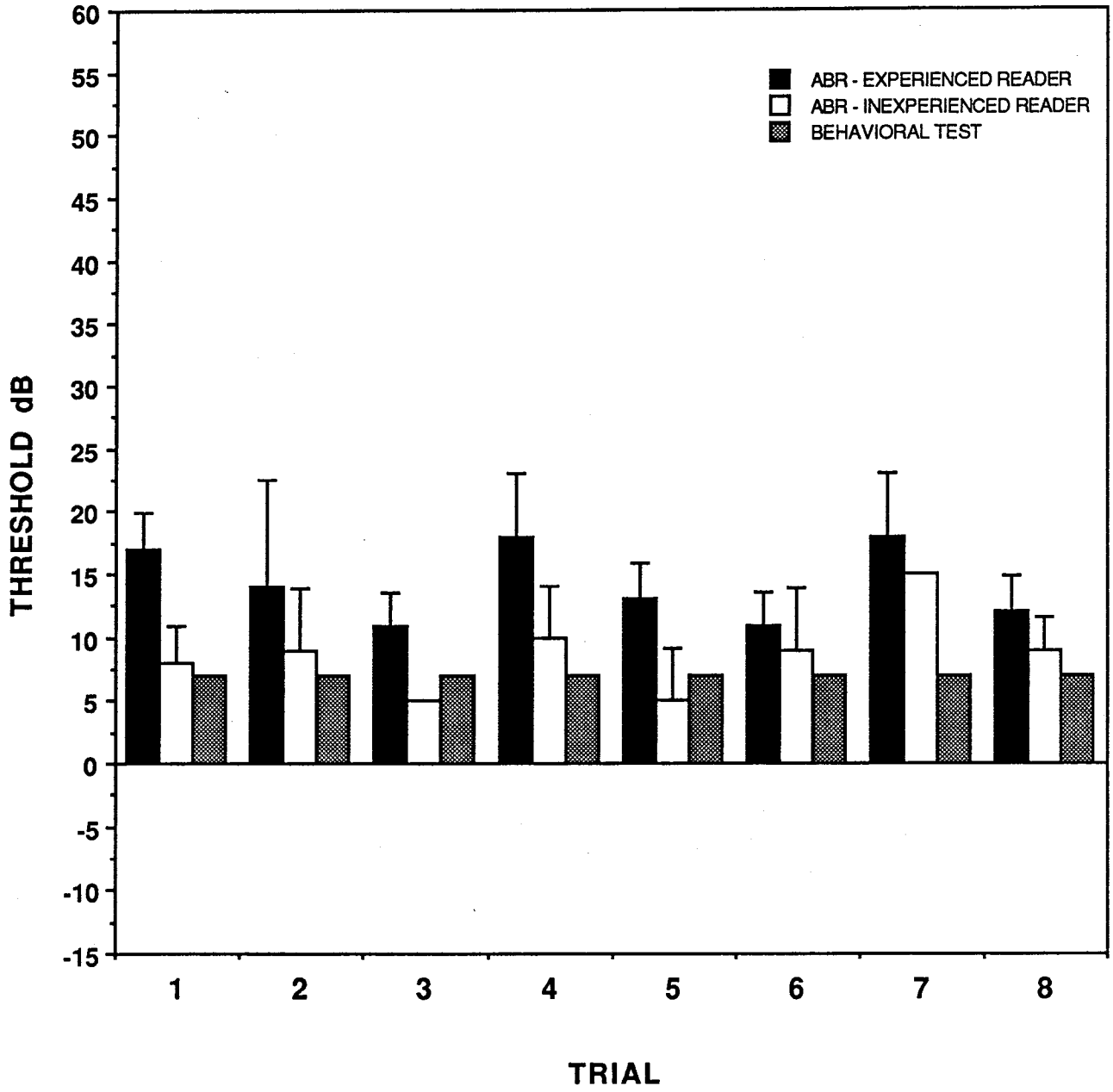


BLACK REPRESENTS THE MEAN OF THE 500 Hz SN10 THRESHOLD ESTIMATES BY EXPERIENCED READERS

WHITE REPRESENTS THE MEAN OF THE 500 Hz SN10 THRESHOLD ESTIMATES BY INEXPERIENCED READERS

SHADED REPRESENTS MEAN BEHAVIORAL THRESHOLD ACROSS SESSIONS FOR SUBJECT #3

500 Hz THRESHOLD ESTIMATES FOR SUBJECT 4

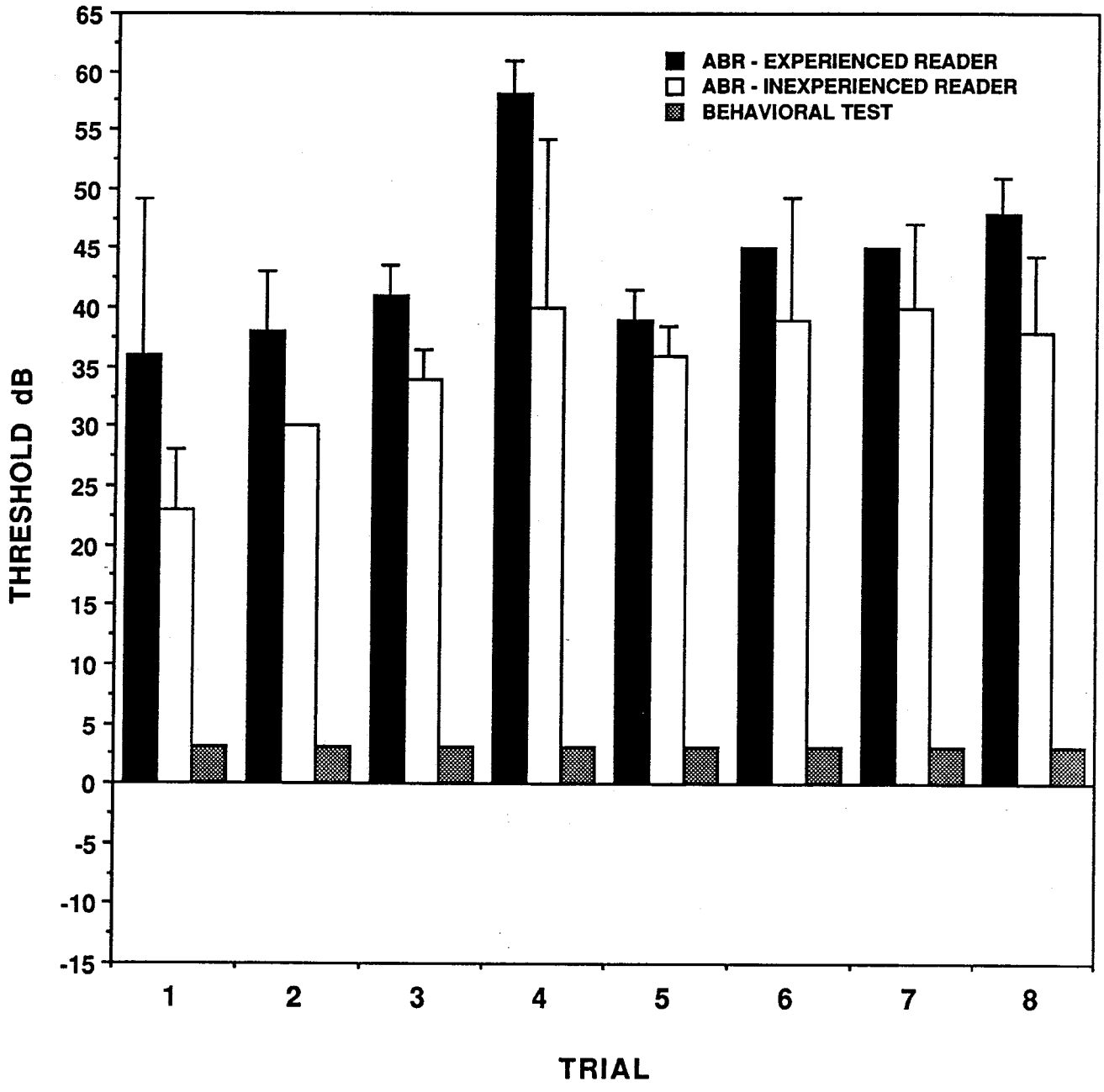


BLACK REPRESENTS THE MEAN OF THE 500 Hz SN10 THRESHOLD ESTIMATES BY EXPERIENCED READERS

WHITE REPRESENTS THE MEAN OF THE 500 Hz SN10 THRESHOLD ESTIMATES BY INEXPERIENCED READERS

SHADED REPRESENTS MEAN BEHAVIORAL THRESHOLD ACROSS SESSIONS FOR SUBJECT #4

500 THRESHOLD ESTIMATES FOR SUBJECT 5

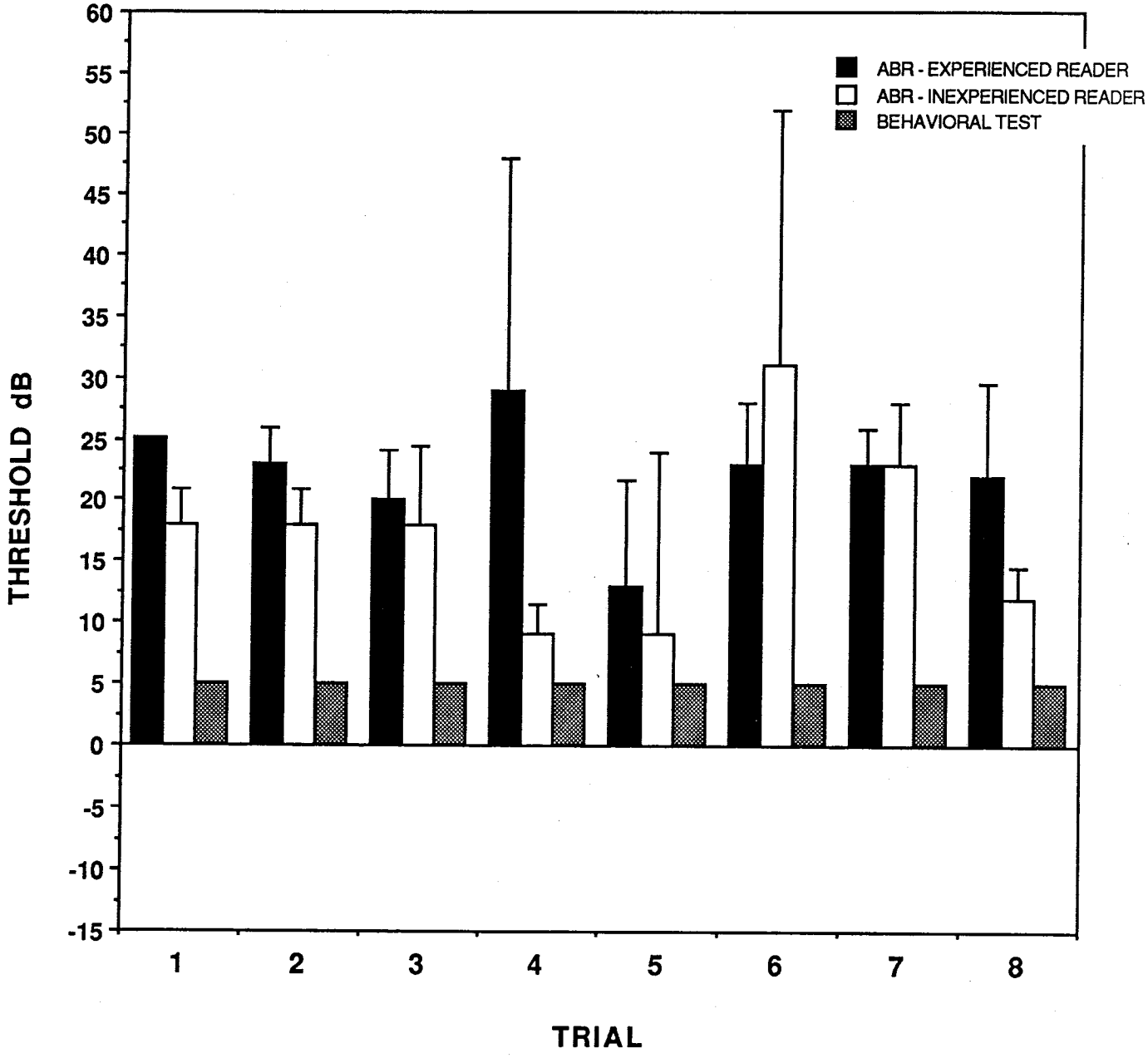


BLACK REPRESENTS THE MEAN OF THE 500 Hz SN10 THRESHOLD ESTIMATES BY EXPERIENCED READERS

WHITE REPRESENTS THE MEAN OF THE 500 Hz SN10 THRESHOLD ESTIMATES BY INEXPERIENCED READERS

SHADED REPRESENTS MEAN BEHAVIORAL THRESHOLD ACROSS SESSIONS FOR SUBJECT #5

500 Hz THRESHOLD ESTIMATES FOR SUBJECT 6

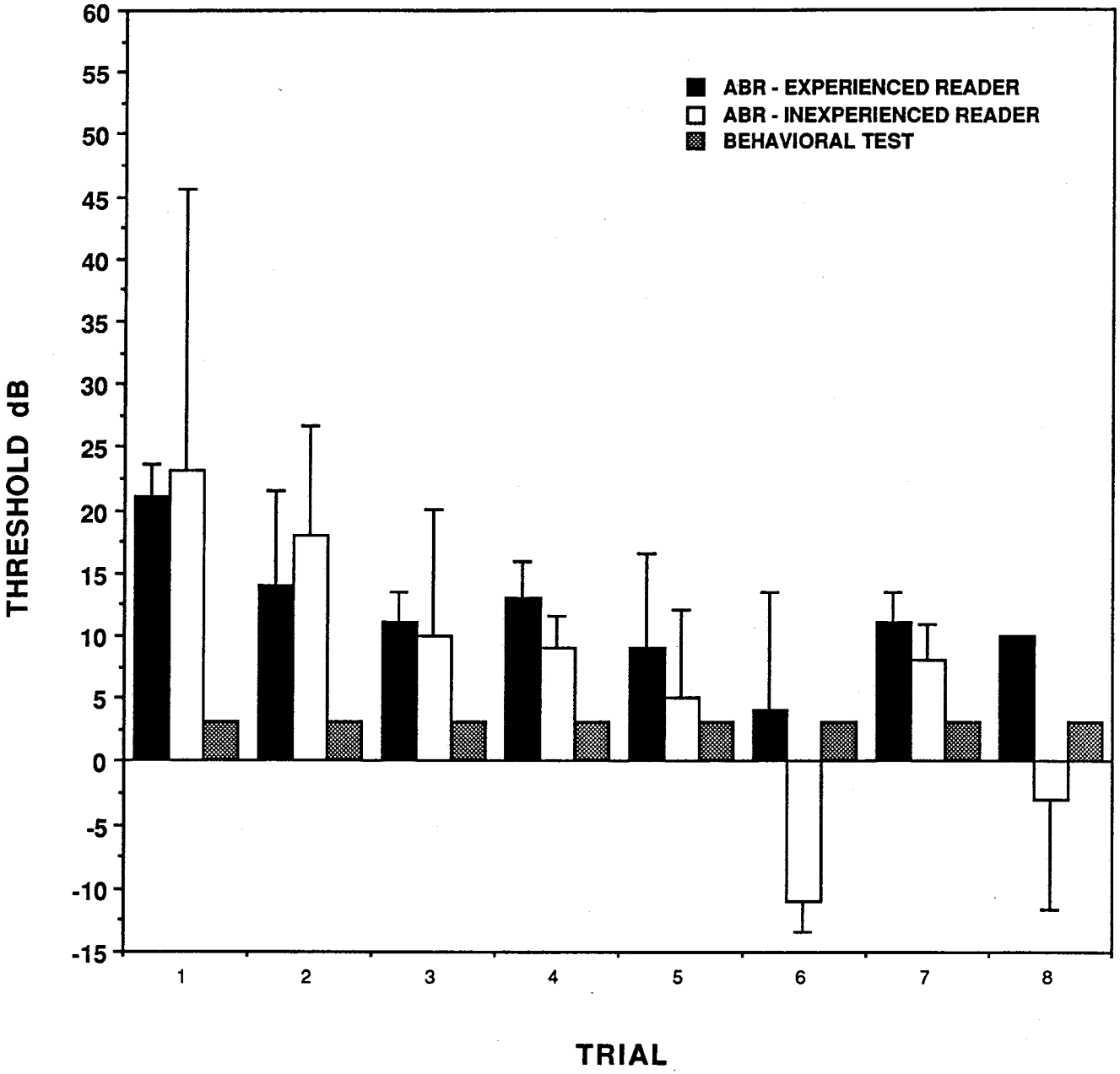


BLACK REPRESENTS THE MEAN OF THE 500 Hz SN10 THRESHOLD ESTIMATES BY EXPERIENCED READERS

WHITE REPRESENTS THE MEAN OF THE 500 Hz SN10 THRESHOLD ESTIMATES BY INEXPERIENCED READERS

SHADED REPRESENTS MEAN BEHAVIORAL THRESHOLD ACROSS SESSIONS FOR SUBJECT #6

500 Hz THRESHOLD ESTIMATES FOR SUBJECT 7

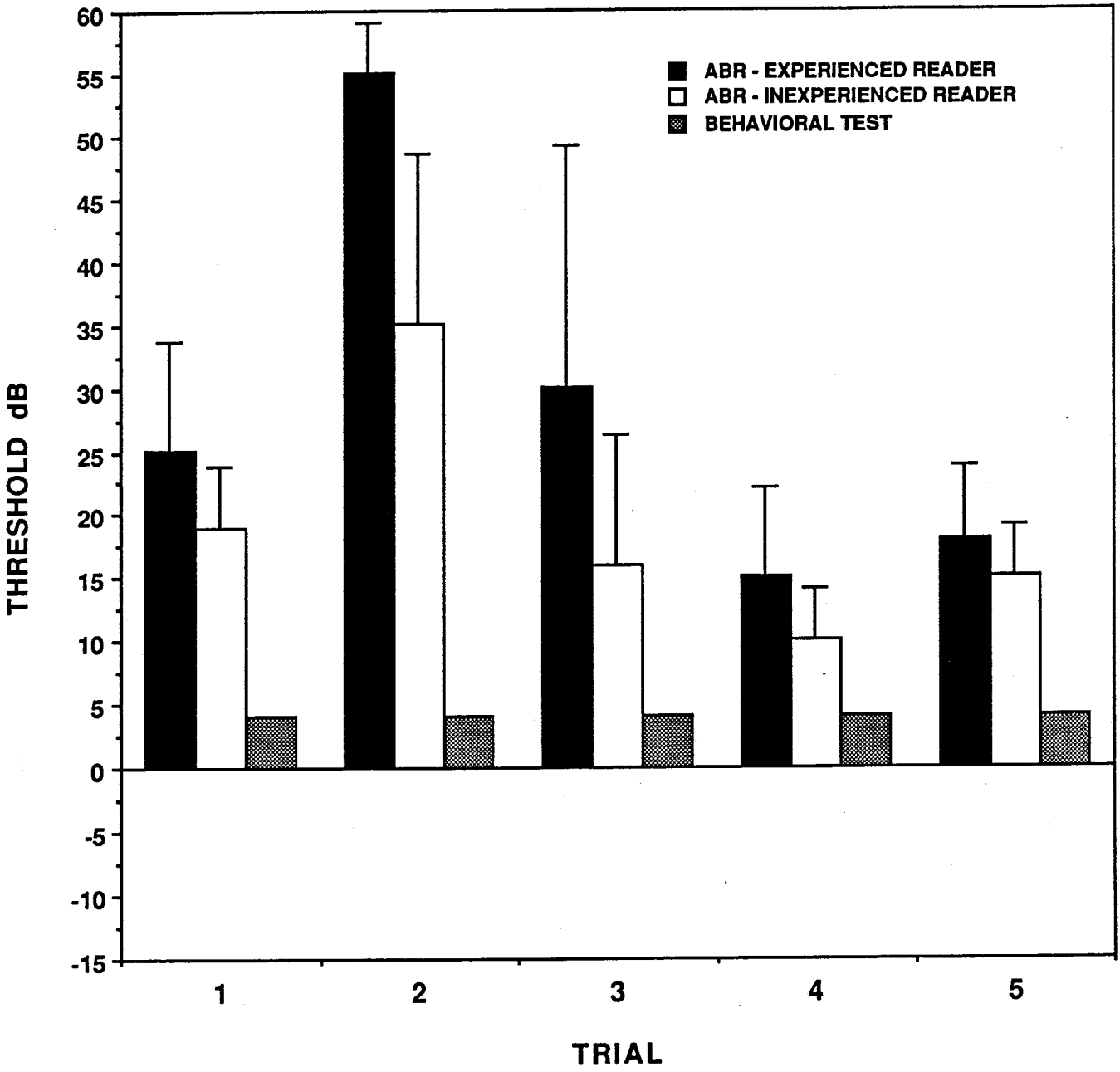


BLACK REPRESENTS THE MEAN OF THE 500 Hz SN10 THRESHOLD ESTIMATES BY EXPERIENCED READERS

WHITE REPRESENTS THE MEAN OF THE 500 Hz SN10 THRESHOLD ESTIMATES BY INEXPERIENCED READERS

SHADED REPRESENTS MEAN BEHAVIORAL THRESHOLD ACROSS SESSIONS FOR SUBJECT #7

500 Hz THRESHOLD ESTIMATES FOR SUBJECT 8



BLACK REPRESENTS THE MEAN OF THE 500 Hz SN10 THRESHOLD ESTIMATES BY EXPERIENCED READERS

WHITE REPRESENTS THE MEAN OF THE 500 Hz SN10 THRESHOLD ESTIMATES BY INEXPERIENCED READERS

SHADED REPRESENTS MEAN BEHAVIORAL THRESHOLD ACROSS SESSIONS FOR SUBJECT #8